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DEEP CAVITY PHOTOGRAPHED BY SHADOWLESS LIGHT

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CONTROL AND REDUCTION OF SHADOW IN INDUSTRIAL PHOTOGRAPHY

Sheldon H. Hine, APSA*

THE NEED FOR photographs that are virtually free from troublesome shadows, when complex apparatus is the object before the camera, has been fulfilled for several years by means of the apparatus and techniques described in this paper. The lighting equipment in question produces photographs of unique character that are desirable not only because of the absence of shadows but also because they provide economies to the photographer. There are savings in the time for set-up of equipment, for preparation of the object, for taking the pictures, and for after-treatment of the photographs such as blocking and retouching. The results are reproducible, even in the hands of inexperienced operators. It is believed that these tools and techniques constitute a forward step in the endeavor to make photography a science rather than an art.

In this paper the maximum practical image sharpness is assumed, as all work is done with apochromatic process lenses on photographic material having optimum resolving power and scale characteristics, and processed for optimum resolving power. Since the subjective term "sharpness" is a function of actual resolving power and viewing conditions or distance, and such practical maximum resolving power is easily achievable. Effort has been expended, therefore, toward the production of photographs which may be described as having, in addition to high resolving power, a characteristic we call *High Revealing Power*.

Before analyzing the diverse methods by which shadows are controlled in photography, it may prove helpful to discuss light and shadow briefly. Reduced to bare essentials, monochromatic photographs are composed of highlights and darker areas or shadow with interconnecting intermediate tone values. Each may serve a useful purpose, but the greater burden of depiction is on the highlights and lighter tone values.

Shadows are used in controlled lighting to create visual effects, conceal unwanted detail, create pattern effects, to serve as a foil or contrasting value for the highlights. They rarely serve any other useful purpose, since they reveal no detail and provide little information.

In a normally lighted scene or picture the eye automatically and instinctively seeks and holds on the lightest area or object. It is with effort that the eye then explores the darker areas seeking secondary meaning. In the lighter areas or areas free from shadow the eye finds the greatest amount of information. In a lighted scene an opaque object always casts shadow in some form or degree. The axiom that Shadow Conceals, Light Reveals, can therefore be stated as self-evident.

In these more important uses to which photographs are put today, shadows, *per se*, are undesirable. It follows then that photographs completely free from shadow will carry more information and do a better job than photographs containing undesirable shadows. These shadow-free photographs may be described as possessing *High Revealing Power*.

That better methods are sought to produce shadow-free photographs is obvious from the many attempts by photographers to design equipment or to develop a technique which they hope will eliminate shadows in their photographs. None of these methods, because of various disadvantages, has received general acceptance in the profession or in industry.

Fig. 10. First photograph made by a police officer using Class B Hinelite. The cover photograph, made by Class A shadowless lighting, illustrates the manner in which deep cavities can be illuminated by that type of lighting equipment.

Review of Shadowless Lighting Techniques

The investigations, tests, and actual use of shadowless lighting of many types which have been proposed, described, patented, and exploited in various ways during the last quarter of a century may be described briefly.

Completely shadow-free photography is not achievable with any normal commercial equipment in use today. It is achievable with highly specialized equipment when used with certain subjects under carefully controlled conditions. However, reduction of shadow area and density to a point of *practical* nonexistence is feasible by either of two methods.

As work with this type of illumination has progressed, it became increasingly obvious that front light, which is dogma in shadow reduction, need not be flat light. The resultant photographs need not be "flat" in contrast but can be made to sparkle with brilliance and fine detail. Incident angle and surface character also assumed more importance because they, together with linear perspective, scale, and in some instances the inverse square law, must carry the burden of suggesting form and relief in a two dimensional picture.

Probably the oldest, and possibly the most widely misunderstood form of "shadowless" light is the overcast sky type. This is the flattest form of illumination, but it is not shadowless. Uniform light reaches the subject from all points of the sky hemisphere. Conse-

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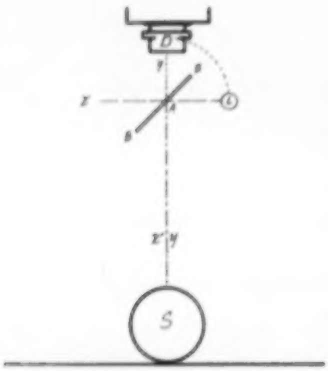


Fig. 1. The beamsplitter BB, at 45° both to the lens axis DS and the light axis LX is located so that the distance from the beamsplitter to the lamp AL is equal to the distance from the beamsplitter to the lens diaphragm AD. This has the same optical effect as locating the lamp at D in place of the lens diaphragm.

Non-axial rays will cast shadows from the subject S but shadow formation is zero for axial rays. Half the light (with 50-50 coatings) is lost by passing through the beamsplitters. The light reflected from the subject toward the lens is also half reflected by the beamsplitter. The theoretical light efficiency of 25% turns out in practice to be nearer 20%.

quently, *any* object blocks off part of this uniform light, causing partial shadow, which in turn causes greying or muddying of the picture. As the complexity of the subject or the picture depth increases, this muddying, caused by shadowing and re-shadowing becomes increasingly serious, causing deterioration of detail in deeper areas and recesses.

Variations of the overcast sky lighting are: the north skylight, tent lighting, "painted" light, and the light flooded white room. These afford a certain amount of control but cannot produce "shadow-free" photographs. They are valuable techniques, especially tent lighting, in photographing highly polished subjects, because the area of specular highlight is rendered large and can be modelled or controlled. In the photographing of highly polished objects, the diffuse component reflected to the camera lens is negligible, specular reflections carry the burden of depiction.

This paper deals primarily not with highlight areas but with the reduction of shadow in a photograph. However, the effect of various lighting treatments upon the character and area of highlight, especially upon specular highlight, has a very important bearing upon both the revealing power and visual appearance of the final print. A large glare or specular highlight can conceal detail as effectively as shadow area conceals it.

As lights are refined and reduced in size for reduction of shadow area, highlight area, (especially specular highlight) is reduced in size and the photographer becomes increasingly dependent on the diffuse component of the light reflected from the subject for the production of the photograph. Indeed, in the final practical refinement in reduction of shadow area to be discussed later, specular reflections become so intense and so small in area as to cause trouble. They appear to resemble intense white dust spots. It becomes evident that no form of shadow reducing illumination is indicated in the photography of highly polished objects.

In a normal photographic lighting set-up, shadow area is compressed or reduced in size as the light is moved closer to the camera. This means for reducing shadows can be continued until the light is in physical contact with the lens. But still appreciable shadow is seen by the lens due to parallax. Here further progress in shadow reduction divides into two approaches. One continues to move the effective light source to the lens axis by means of a beam splitter and appropriate optical components, thus reducing parallax of the lens axis and light axis to zero. At first glance this would seem to complete the whole subject, but it will be seen that much further development is required. The ultimate in shadow reduction, using this method, is physically and theoretically unachievable.

By another method of shadow reduction, a similar light is added on the opposite side of the lens. This produces two shadows, though each is reduced to one half of its original depth by the light opposite. This is hardly an acceptable condition since each shadow continues to be quite prominent.

"Shadowless" Ring Lights

This procedure, however, is the starting point for many of the so-called "shadowless" lights which have been developed. Usually four more lights are added, making a ring of six lights about the lens. A further refinement is the construction of a circular reflector in which a

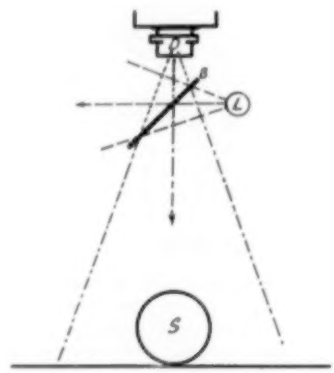


Fig. 2. Diagram illustrating the limitation on the field of view that is possible with a beamsplitter in front of the camera lens. Another complication of this arrangement is the need for trapping all the light which passes through the beamsplitter from the light source so that it will not reflect from the camera side of the beamsplitter, causing ghosts and fog.

number of lights are placed. The lens is located centrally in any such array in such a position that neither the lights nor reflector obstruct the lens. The claims that these methods produce "shadowless" illumination are fallacious. Each light in the ring casts its own shadows, which can only be partially filled by the other lights. These circle lights in many cases provide thoroughly acceptable illumination. But their illumination is never completely "shadow-free" and the deeper recesses in complex subjects suffer from deficient illumination.

For reference and identification purposes the beam splitter or optical method of lighting to reduce shadows may be called optical Class A, and the ring type lights, Class B. Class A methods place the light inside the lens cone and Class B methods place the lens inside the light. As the Class A technique is fully developed it becomes a precision instrument capable of achieving hitherto impossible results. As Class B methods are fully developed they become a thoroughly practical tool, producing top quality engineering photographs with a minimum requirement for effort and experience. Results with both

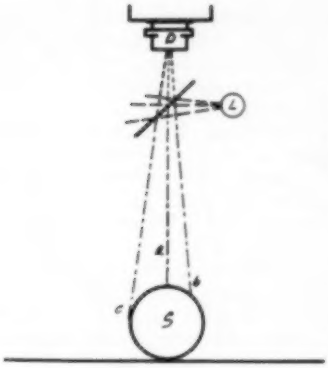


Fig. 3. The modeling effect inherent in Class A shadowless lighting. Assuming a spherical subject S which is predominately neither matte nor glossy, axial light beam *a* strikes at a 90° angle and maximum light is consequently returned to the lens. Ray *b* strikes at a lower incident angle so a smaller amount of light is reflected back into the lens. Ray *c* strikes at or near zero incident angle so near zero light is reflected to the lens.

techniques are consistent and reproducible. In developing Class A light to its practical ultimate the light/lens/beam splitter arrangement shown in Figure one is basic.

The excellent results achievable with Class A lighting are had at the cost of very poor light efficiency, and the method is indicated only for small objects, deep cavities and small, very complex machinery. Areas about 4 × 4 feet are a practical maximum, with little limit on minimum size.

For areas larger than 3 × 3 feet, some class B lights provide acceptable illumination for many subjects. The ultimate development in this method (to be described later) does quite well down to 6 × 6 inches. Because there is little limit to the amount of power which can be utilized by adequately engineered Class B units, they can be made to cover quite large areas.

To be of practical value, any Class A unit must be capable of illuminating a useful angle. Figure two shows a basic condition for such an instrument. The maximum field angle possible with such a device is limited by the permissible physical size of the unit and the critical angle of the beam-splitter surfaces.

In the case of non-axial rays, not just the marginal rays, parallax again introduces penumbral shadow. If both the light source and lens stop in use were true points, no parallax would be present and true shadow-free photography of general type subjects would be achieved. As the size of the effective light source and lens stop in use depart from true points, parallax between points within the areas increases and so does the area of the penumbral shadow seen by the lens. Even under the most unfavorable conditions of relatively broad light source, (usually a high power projection lamp with unstopped condensers) and wide open lens aperature, penumbral shadow area is considerably less than half the magnitude of that achievable with any Class B light.

When the condenser system is refined so the size of imaged filament is greatly reduced, and when used with a small lens stop, penumbral shadow is reduced to a point of practical nonexistence. Also, when the effective light source is both coincident with the lens stop and coaxial, other phenomena occur.

It was mentioned earlier that front lighting need not produce flat appearing photographs. Indeed, the finest possible modeling consistent with high revealing power is inherent in these techniques, as shown in Figure three, in which highlights are formed on points of the subject closest to the camera and at maximum incident angle, with light decreasing as form recedes terminating in a dark line which outlines forms and separates planes with excellent clarity and relief. This coincides perfectly with the rule of drawing which says, "Highlights come forward, shadows recede."

Further exploration of possible arrangements of the basic Class A components, (Figure one) shows that when the distance between the light source and the beam-splitter is greater than the distance between the lens diaphragm and the beamsplitter, the light source is in effect behind the lens. Therefore the shadow cast by the subject on a background immediately behind the subject is smaller than the subject and it will be completely covered by the subject. This condition is indicated for the photography of external surfaces to provide true shadow-free pictures.

If the above condition is reversed and the distance from the light source to the beamsplitter is less than the distance from the beamsplitter to the lens diaphragm,

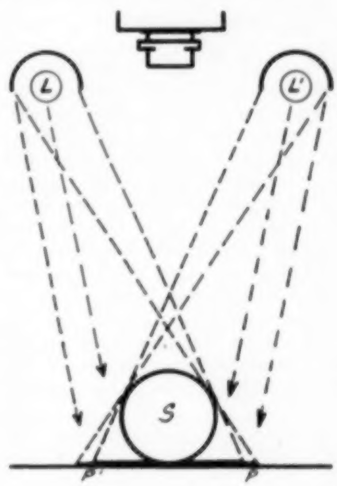


Fig. 4. Diagram of Class B shadowless lighting arrangement. Lights at L and L' cast shadows at P and P' behind subject S at the same time each light partially cancels (by illumination) the shadow cast by the opposite lamp.

the light source is in effect in front of the lens and the opposite effect is produced on the penumbral shadow. In such case, the edge of the shadow will be seen by the lens. Sometimes this effect is useful in producing dark outlines around convex and exterior forms. This condition is especially indicated for cavity photography. Since the light is nearer the cavity than is the lens, illumination of interior surfaces is at an optimum.

Ring Lighting Arrangements

The alternate approach to the problem of shadow reduction is through the Class B lights, which reduce the depth or value of shadow area by multiple cancellation or multiple illumination. Ring lights place the lens inside the light, or surround the lens with anything from a small gas discharge tube or a mirror with a hole in it for the lens, to a large doughnut reflector in which a number of lights are mounted. While these lights are simpler to construct, and higher in efficiency than Class A arrangements, they do produce considerable penumbral fuzz around all objects. This is especially notice-

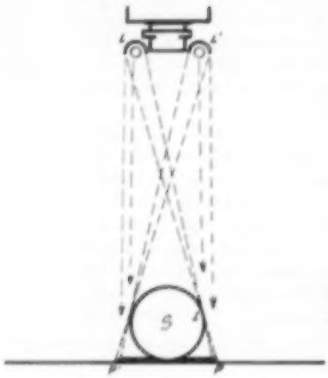


Fig. 5. Diagram for small ring light surrounding the lens axis Since the radial width of the lamp tube is small, the penumbral shadow cast by the subject S is consequently narrow and dense. Light ray LP touches the subject at zero incident angle, hence the outline of the spherical subject is quite dark, being illuminated slightly by light ray L′. All objects in the picture or parts of the subject are surrounded by a grey halo or penumbra that is rather sharply defined.

able when photographing objects against a white background and when the subject is either deep or of complicated form.

One of the early "shadowless" lights was built by Fred Peel in the early thirties. He used it on a studio camera for portraiture and figure studies, and for this purpose it served quite well. It was a large circular reflector in which a number of photoflood lamps were mounted. Since it was of considerable area, results were both relatively shadowless and flat. The light source was so large that modeling due to the incident angle effect shown in Figure three was not effective. And of course catch lights in the eyes of the subject were enlarged. This form of specular highlight is an image of the light itself and would be present on any glossy form, progressively increasing in area as curved surfaces approach a plane surface perpendicular to the axis of the array, at which point it would be an extended area of glare highlight.

Figure four shows shadow formation, shadow cancellation, and highlight formation with such a ring light of large diameter.

In the early nineteen forties Folmer Graflex Company, together with the General Electric Company, developed a surgical camera with a self contained circle flash tube. This FT 428 tube is $4^1/_2$ inches in diameter and fits snugly in its circular reflector around the lens. The arrangement represents nearly ultimate development in single circle illumination.

The FT 428 tube, and even smaller counterparts, are available today as accessory units with reflectors for both miniature and commercial cameras. An FT 428 tube mounted on a Speed Graphic camera provides just about the optimum illumination for *quick record* photographs of almost any fairly large object except those with highly polished surfaces. Such cameras, because of their convenience, are commonly used by surgeons and dermatologists for recording progress, photographing pathology, or for instruction and sales purposes.

The most serious shortcoming of these cameras is the fact that the penumbral shadow is so compressed that it becomes quite dense. In many cases the incident angle or dark edge effect merges with the small but heavy penumbral shadow causing loss of outline. This effect is illustrated in Figure five. Another shortcoming is that, when used for cavity photography, such as oral photography by dentists, these circle lights are found lacking in efficiency. The diameter of the circle of light is usually larger than the cavity itself, and cannot fully illuminate the sides and back of the cavity.

As was mentioned above, Class B lights have been developed in a wide range of physical forms. Several significant types should be mentioned. An old and often recurring form is the mirror placed at 45° to the lens. Through this mirror a hole is cut for the lens. A light, often of random characteristics, is placed to one side at 45° to the mirror, so it is reflected to the subject from roughly the lens position. The effectiveness of this set-up depends upon the care with which it is assembled and the characteristics of the light source, and physical bulk, in addition to the inevitable penumbra.

One deficiency of this arrangement is shown in Figure six.

Sometimes an array of one or more concave mirrors is used to distribute the light to best advantage and such an arrangement, when properly adjusted for the particular case, can produce good results, but the field of light

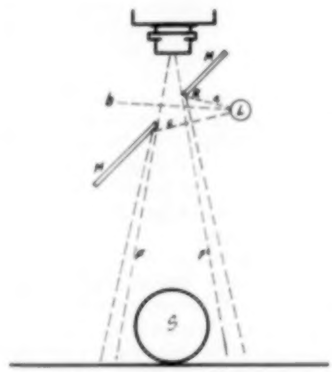


Fig. 6. Section through a perforated mirror Class B arrangement. The mirror M has a hole in it roughly coinciding with the field angle of the objective lens. Light rays *a* and *b* reflect from the mirror at the edge of the hole. Since this point R lies outside of the field angle, the rays are reflected outside the camera field and are relatively useless. Light rays passing through the hole in the mirror, *b*, also are lost.

With smaller light sources and most types of spotlights, the field of the lens coincides with the cone of darkness. The mirror may be adjusted angularly to compensate for this defect but the effect is as if a single light source were being used at one side of the lens barrel. Such a light is not a shadow-reducing arrangement.

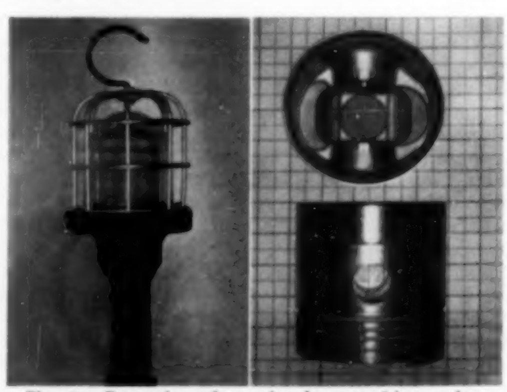


Fig. 9. Examples of two hardware subjects photographed by means of Class A Hinelite. Shadow concealment is virtually perfect and no blocking is needed.

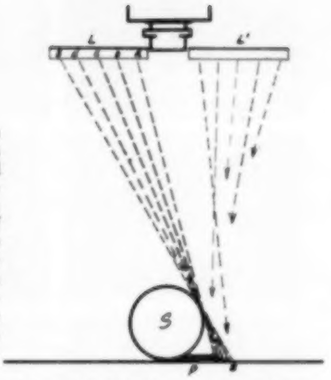


Fig. 7. Section through the axis of a gradedcircumferential light and camera set-up like that shown in Fig. 8. The plane of light surrounding the lens varies in intensity exponentially. This is accomplished simply by varying the spacing between turns in a helix of fluorescent tubing.

The penumbra formed by such a light source also has exponential densities, decreasing to a very low density at the outer edge. This outer shadow band of weak penumbra is cancelled by the direct light from the opposite side of the lens. Since the direct light is applied to the penumbra exponentially in the inverse order, the entire shadow is effectively cancelled except at the very edge of the subject. Even there the shadow is soft and, in most cases, so low in density as to be negligible.

In the case of cavities, of course, there is inevitable shading. Should this be serious, the Class A lighting arrangement is indicated.

may be too restricted and the particular set of components too inflexible for general use.

Some photographers have tried the commercial Circline fluorescent tubes in various diameters but usually find that their light output is insufficient and, since they are single tubes, the results of such lights are similar to Figure five but with a larger penumbra due to their larger diameter.

The Class B Hinelight

In pursuing the elusive all-highlight photograph, a broad circle, broader than any of the foregoing was considered. Such an arrangement, it is obvious, violates the principles of shadow-reduction, for the shadow area would be both broad and well defined.

With the broad flat light as a base, the intensity of the illumination was varied radially and the first real progress in shadow-reduction was immediately evident.

The final configuration, which is called "Graded Circumferential Light," was evolved. Figure seven shows this new configuration and describes the principles upon which it operates.

When the conditions shown in Figure seven are established so that light is intense at the center, as near to the periphery of the lens mount as physical conditions permit, and when this light intensity decreases exponentially radially, a new type of shadow formation and cancellation occurs.

This graded concentric light also produces highlight formation on most subjects which increase the apparent brilliance of the finished print. This is also explained in Figure seven.

The validity of this configuration was obvious with the first test photograph, and little alteration has been found desirable other than the mechanical aspects which make it practical for general industrial photography. Thus, with these two lights which complement each other, it appears that the techniques of shadow-reduction in photography may begin to gel around a practical terminal development consistent with presently available components and knowledge.

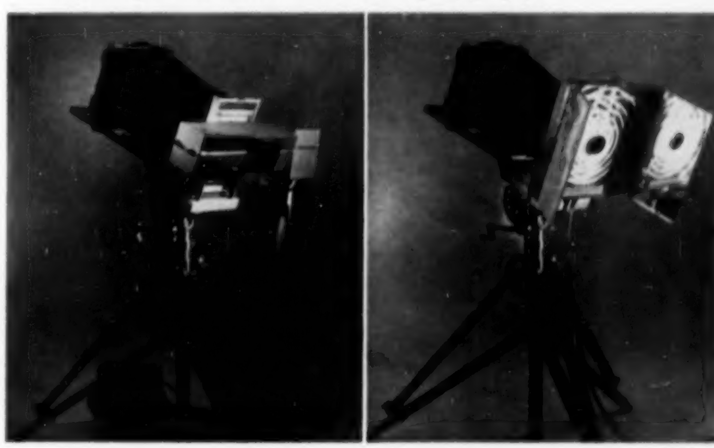
Construction Details of Class A and B Hinelights

From the photographs (Figure eight) of the lights mounted for use it can be seen that both are quite compact and lightweight. Both mount easily and interchangeably on an adapter unit which attaches to a standard Saltzman MR camera stand head. Another unit not shown, attaches to any standard tripod head.

The class A light, utilizing a 1000 or 1250 watt projection lamp, requires forced cooling. To prevent vibration (produced by even the finest blowers) from reaching the optical system, a separate blower made from a cut down tank type vacuum cleaner serves admirably. The fine fabric filters made for such units are left as dust filters, as dust can cause serious trouble if it sticks to the beam splitter. These blowers supply too much air so a resistance and junction box has been added, which reduces both motor speed and noise. Since the light trap absorbs considerable energy, it becomes quite hot, so the air flow is metered inside the light housing to cool the trap also. The trap is composed of four pieces of black cararra glass to which a reflection reducing coating has been applied. Two of these are arranged in the form of a deep "V" with the sides being closed by two additional pieces. These are so supported that absorption takes place even in the corners and at the apex of the "V" without any reflection points. This trap is, so arranged that any ray from the light is reflected a minimum of seven times, thus absorption of a high order is achieved.

To extend filament life, the entire lamp housing and optical system rotate about the axis of the light. As the camera is tilted throughout a range of 90°, the light can operate in its normal base down position.

Fig. 8. Shadowless lighting equipment of the Class A type (left) and Class B type (right) mounted on an ordinary 8 × 10 inch view camera. The Class A Hinelite is equally effective when used with smaller cameras, including 35mm film cameras for color photography.



To facilitate control of the lens stop, an extension lever has been added to the stop ring which carries an index and handle at its outer end. The diaphragm calibration has been carried to an extension sector which projects past the front camera upright.

In use, little more than framing, focussing, and arranging the subject is required. When it is essential to know in advance exactly what details will be recorded in the photograph, this light is a great boon. Any part of the subject which is lighted is also recorded, exactly in the amount and extent to which it is lighted. Thus, if light reaches any particular component, that area will also be shown in the photograph.

The Class A unit, being an optical device, requires the care normally given such equipment and is not usually indicated as a device for general shop use. In a well staffed and equipped photographic laboratory, however, it can and does serve well and consistently.

Photographs made with this light may appear somewhat strange at first to photographers accustomed to seeing and interpreting shadow and side lighting effects. When only pure outline and form are shown, a bit of familiarization is sometimes necessary. In some cases an additional light may be used as a concession to visual appearance and photographic tradition. Since observers are accustomed to top lighting, in which case some highlights appear on the top of all forms, a soft top light may be added to produce this effect; not strong enough to produce noticeable shadows. Such an arrangement often makes a more visually pleasing photograph of even the most prosaic subject without in any way reducing revealing power.

The Class B unit makes life much easier for the photographer. In most set-ups with mechanical and electronic gear for which these "shadow-free" lights are largely used, little more is necessary than framing, focussing, and exposing the film.

As can be seen in Figure eight, the Class B unit is built around an exponential helix of 10mm fluorescent tubing. It operates on 6kv at 125ma from a special transformer. An Alzak reflecting surface is placed behind the lamp to increase its efficiency. The reflector wings are made of specular Alzak to serve both as the protective cover when the light is not in use and as a supplementary means of directing additional light onto darker colored subjects. These reflector wings afford a limited amount of control of the light which often proves quite useful. Pre-production prototypes have since been made with an additional pair of reflector wings at top and bottom made of polyester fibreglass. These carry a primary interlock circuit as required by Underwriters' Laboratories, Inc. and in general are tricked up to make an attractive and practical unit. At present standard 3500° white tubing is used but it appears that phosphors richer in red may be available soon so that, with proper filtration, they will be suitable for color photography.

Fig. 11. Simple, straightforward, commercial photograph made with a minimum of set-up by use of a Class B Hinelite. No retouching or art work is needed.

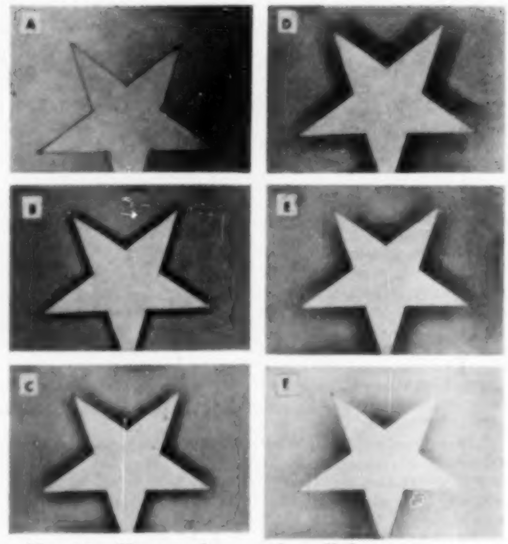


Fig. 12. To test these various lights, a test target was devised which shows pure shadow formation completely divorced from all other variables of color, form, texture, incident angle, etc. A 2 inch star was cut from white Bristol board and supported three inches above a sheet of the identical material. If shadow cancellation were perfect, virtually no outline of the star would be seen. Any shadow is immediately obvious. Results obtained using the test target are shown above. A. Line penumbra produced by Class A light. B. Penumbra produced by FT 428 flash tube surrounding the lens. C. Penumbra produced by 3 concentric turns of a light tube. D. Penumbra produced by Circline tube 9 inches in diameter. E. Penumbra produced by 6 concentric turns of a fluorescent tube, spaced exponentially. F. Penumbra produced by 8 turns of exponentially spaced fluorescent tube, the complete Class B Hinelite.

Perhaps one of the more desirable characteristics of this graded circumferential light is that results are consistent in character from time to time and from operator to operator, and a uniform style can be established. However, some may object to the inflexibility of these fixed lights, which permit no personal control. If lighting variations are desired, these lights provide fine key lighting, to which other lighting may be added for emphasis, design, shadow pattern or whatever, without cross shadowing, which almost always occurs when conventional key lights are used.

Unfortunately, the working photography produced by these shadow-free lights is classified so it cannot be illustrated here. The examples shown are largely academic and test subjects, but they serve to show results which are produced. No retouching whatever has been done on any of the photographs. Indeed, virtually none is ever done on the working photographs, with the result a substantial saving in both time and production cost.

THE KINETICS OF DEVELOPMENT BY 1-PHENYL-3-PYRAZOLIDONE

T. H. James and W. Vanselow*

ABSTRACT

The rate of development by 1-phenyl-3-pyrazolidone (Phenidone Developing Agent) in the absence of added bromide increases with increasing pH over the range 5.5–9. The rate is independent of pH above 9. The pH dependence below 9 is too small to be accounted for by the assumption that only the ion is active, and it is suggested that the non-ionized form is active as well. The rate of development is directly proportional to the 1-phenyl-3-pyrazolidone concentration at pH above 9, but varies as about the two-thirds power of the concentration at pH 6.6. The rate is diffusion-controlled above pH 9. The activation energy calculated for the chemical reaction of development is 14–16 kcal/mole, and the value increases with decreasing exposure. The activation energy of fog formation is 18–19 kcal/mole. In the diffusion-controlled region, the calculated activation energy is 8–9 kcal/mole, and is independent of exposure. Potassium bromide, added in sufficient amounts, decreases the rate of development, and diffusion is no longer rate-controlling even at fairly high pH. Sulfite is without significant effect on the rate of development. The rate of development by 4-methyl-1-phenyl-3-pyrazolidone and 4,4-dimethyl-1-phenyl-3-pyrazolidone is the same as that by 1-phenyl-3-pyrazolidone at pH above 9 and in the absence of added bromide. At pH 6.5, the activity decreases with addition of each methyl group. Chromatographic experiments indicate that 1-phenyl-3-pyrazolidone and its derivatives are adsorbed by silver bromide, and the adsorption becomes weaker with addition of each methyl group.

The developing action of 1-phenyl-3-pyrazolidone (Phenidone Developing Agent) and its ability to activate hydroquinone were discovered in 1940 by J. D. Kendall.[1] Several papers have been published since[2,3,4] describing the superadditive properties of mixtures of this agent with certain other developing agents, such as hydroquinone, *p*-(methylamino)phenol, and ascorbic acid, and 1-phenyl-3-pyrazolidone has been suggested as a substitute for *p*-(methylamino)phenol in some practical M-Q formulas. However, a knowledge of the kinetics of development by 1-phenyl-3-pyrazolidone alone is important to the proper understanding of the behavior of the mixed developers, and little has been published on this subject. The present paper deals with the kinetics and mechanism of development by 1-phenyl-3-pyrazolidone alone, and by some of its derivatives, used in formulas of relatively simple composition.

Experimental

A high-contrast, positive-type emulsion of relatively narrow grain-size distribution was used in all work except that on the temperature-dependence. The emulsion was essentially the "Emulsion G" used in some previous work.[5] A harder emulsion, Eastman Fine Grain Release Positive Film, was used for the temperature-variation experiments. The films were exposed under standard conditions on the Eastman IIb Sensitometer. All solutions were prepared and used under an atmosphere of nitrogen, and with nitrogen agitation, as described in a previous paper.[6] The developing agent was dissolved in a dilute hydrochloric acid solution of pH about 3.5. This solution and the buffer solution were deaerated with nitrogen before mixing, and were mixed under nitrogen for use. Agitation was supplied by irregular bursts of nitrogen passing over the film. (In a few test experiments, air was used for agitation. The activity of the developer under these conditions decreased rapidly because of loss of developing agent by oxygen oxidation.)

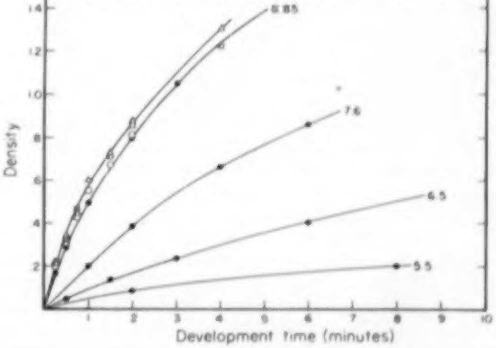


Fig. 1. Curves representing development of the log E = 1.90 step of Emulsion G by 0.005 M solution. The lower pH values are marked on the curves: ○ ○, pH 10.3; □ □, pH 10.5; △ △, pH 13.

1-Phenyl-3-pyrazolidone develops without an induction period under most conditions. The shape of the

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Table I

DEPENDENCE OF RATE OF DEVELOPMENT ON 1-PHENYL-3-PYRAZOLIDONE CONCENTRATION AT PH 9.5

Concentration	Rate $(1/t)$	Rate/Concentration
0.000083	0.071	867
0.00025	0.192	768
0.00050	0.392	784
0.00100	0.870	870
0.00500	4.34	868

Table II

DEPENDENCE OF RATE OF DEVELOPMENT ON 1-PHENYL-3-PYRAZOLIDONE CONCENTRATION AT PH 6.6

Concentration	Rate$(1/t)$	Rate/Concentration
0.000167	0.033	200
0.00050	0.090	180
0.00167	0.200	120
0.0050	0.400	80

density-time of development curves is illustrated in Figure one. These curves represent development of Emulsion G at a constant exposure of log E = 1.90, which is on the shoulder of the characteristic curve for this emulsion. The shape of the curves obtained with lower exposures is essentially the same, however.

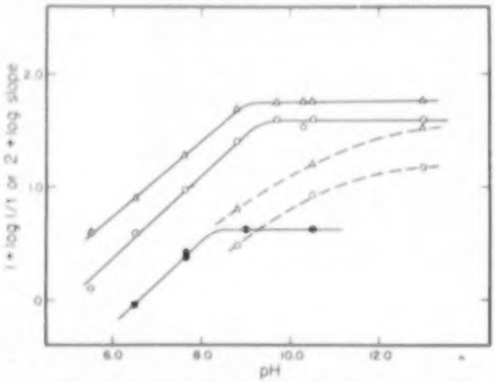


Fig. 2. Dependence of rate of development on pH. ○ ○, $1/t$ rates for 0.005 M solution; ● ●, $1/t$ rates for 0.0005 M; △ △, slope rates for 0.005 M. ——, No added KBr; - - -, 0.05 M KBr.

Figure one shows the effect of variation of pH on development. The development curve shape does not depend on pH to any significant extent. The rate of development increases with increasing pH up to about 9, at which point it becomes independent of pH when the solution contains no potassium bromide. In these experiments, potassium hydroxide was used to obtain a pH of 13, sodium carbonate-bicarbonate mixtures were used to obtain pH between 10 and 11, borate buffers were used in the pH range 8–10, and phosphate buffers were used for all pH values below 8.

The dependence of rate on pH is shown in another way in Figure two, where the logarithm of the rate is plotted against pH for several conditions. The development rate is expressed in two ways. In the first, the rate is taken as the reciprocal of the time required to obtain a density of 0.20. In the second, the rate is expressed in terms of the average slope of the development curve over the density range 0.1–0.3. The solid lines in Figure two represent development by 0.005 M or 0.0005 M 1-phenyl-3-pyrazolidone in the absence of added bromide. The broken curves represent development by 0.005 M 1-phenyl-3-pyrazolidone to which 0.05 M potassium bromide had been added. The rate reaches its maximum at pH about 9 in the absence of bromide, but continues to increase with increasing pH in the presence of the bromide.

Sulfite added in small amounts to the developer is essentially without effect upon development. No effect was observed when sulfite was added in amounts up to 0.05 M to a 0.005 M 1-phenyl-3-pyrazolidone solution at pH 8.85. Likewise, no effect was observed when sulfite was added in amounts up to 0.01 M to a 0.002 M 1-phenyl-3-pyrazolidone solution at pH 6.5.

The rate of development at pH above 9 and in the absence of added bromide is directly proportional to the concentration of the developing agent. This is shown by the constancy of the rate/concentration values given in Column 3 of Table I. At pH below 9, however, the rate variation is less than proportional to the concentration. Table II gives some data for development at pH 6.6. The ratio of rate to concentration decreases with increasing concentration of 1-phenyl-3-pyrazolidone. The rate at this pH is approximately proportional to the two-thirds power of the concentration.

The rate of development by 1-phenyl-3-pyrazolidone increases with increasing temperature. This temperature-dependence was investigated over a range of 5–40 C. When the solution contained no potassium bromide and the exposure was in the shoulder region of the characteristic curve, the temperature-dependence followed the simple Arrhenius equation. This is illustrated for several experimental conditions in Figure three, where a straight line was obtained by plotting log rate against the reciprocal of the absolute temperature. The Arrhenius equation also holds for fog formation, as shown by the two lower lines in Figure three. The slope of the straight line, when multiplied by $R \cdot \log_e 10$, gives the

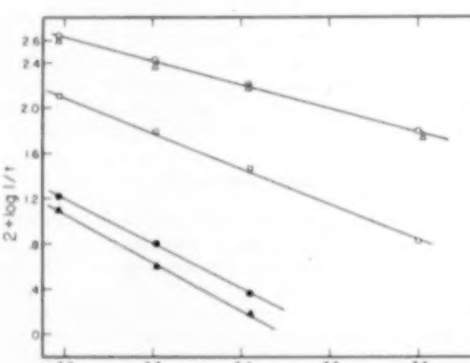


Fig. 3. Arrhenius plots showing temperature-dependence of development. ○ ○, image development, pH 13; ● ●, fog, pH 13; △ △, image, pH 9.5; ▲ ▲, fog, pH 9.5; □ □, image, pH 6.5. The $1/t$ rates for fog are calculated from the times required to give a fog density of 0.10.

Table III

CALCULATED ACTIVATION ENERGIES

pH	Rate Expressed as	KBr Added	Activation Energies for Log E = 2.35	1.15	0.60	Fog
13	slope	0.0000	8	8		
	$1/t$	0.0000	9	9.5	9	18
	$1/t$	0.0167	9.5–14*	11–14*	13–16*	
9.3	slope	0.0000	8	8		
	$1/t$	0.0000	9	9.5	9	19.5
	$1/t$	0.0167	10.5–14*	14	16	
6.5	slope	0.0000	12.5		15–16	
	$1/t$	0.0000	14	15	16	

* Calculated values increased with decreasing temperature.

Table IV

ADSORPTION AND DEVELOPMENT RATE DATA FOR 1-PHENYL-3-PYRAZOLIDONE DERIVATIVES

Compound	Concentration, M	Dye Displacement	Development Rate, pH 5.95 ($1/t$)
1-Phenyl-3-pyrazolidone	0.001	0.62	0.055
	0.010	1.36	...
4-Methyl-1-phenyl-3-pyrazolidone	0.001	0.57	0.042
	0.010	1.12	...
4,4-Dimethyl-1-phenyl-3-pyrazolidone	0.001	0.43	0.023
1-Phenyl-3-pyrazolone	0.001	0.16	0.000
Acetone alone	...	0.16	0.000

over-all energy of activation. The activation energies calculated in this way are listed in Table III for various experimental conditions. Data are included for two lower exposures as well as for the high exposure represented in Figure three. The lower exposures gave satisfactory straight lines on the Arrhenius plot over the range 20–40 C, but the points corresponding to 5 C fell below the straight line. In general, the calculated activation energy was independent of exposure when bromide-free solutions were used at pH 9.3 and 13. When the solutions contained 0.0167 M potassium bromide, however, the calculated activation energy decreased with increasing exposure. At the highest exposure used, the Arrhenius plot did not give a straight line, but a curved line with slope increasing as the temperature decreased. This behavior can be accounted for on the basis of diffusion effects, as will be shown subsequently. At pH 6.5, satisfactory straight lines were obtained for the Arrhenius plot, and the calculated activation energy increased with decreasing exposure, even in the absence of added bromide.

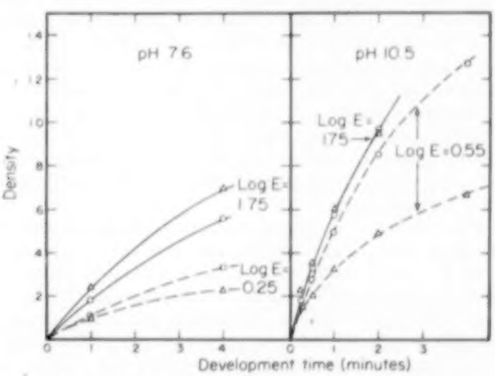


Fig. 4. Effect of dodecyl pyridinium ion on development by 1-phenyl-3-pyrazolidone. ○ ○, water control; △ △, prebathed 45 minutes in 0.001 *M* dodecyl pyridinium *p*-toluenesulfonate.

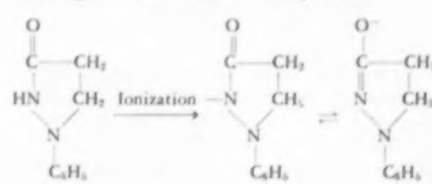
The effect of a quaternary salt on development by 1-phenyl-3-pyrazolidone was tested by prebathing the exposed film in 0.001 M dodecyl pyridinium p-toluenesulfonate solution for 45 minutes. The results obtained at two different pH values are illustrated in Figure four. At pH 7.6, the quaternary salt accelerated development somewhat in the high-exposure region, but decreased it in the low-exposure region. At pH 10.5, the quaternary salt was without effect on development in the high-exposure region, but decreased it in the low-exposure region. The quaternary salt thus causes an increase in contrast and a loss in emulsion speed.

A few tests were made on the 4-methyl and 4,4-dimethyl derivatives. These two compounds showed the same general kinetic behavior as 1-phenyl-3-pyrazolidone. The rates of development by the three compounds were identical at pH 9.7. At pH 5.95, however, the derivatives developed at a lower rate than 1-phenyl-3-pyrazolidone itself, as shown in Table IV.

The adsorption of 1-phenyl-3-pyrazolidone and its derivatives by silver bromide was investigated by the chromatographic method. The technique employed was the same as that previously described for a study of the adsorption of p-phenylenediamine.[7] An uncharged merocyanine dye, 3-ethyl-5-[(3-methyl-2(3H)-thiazolinylidene)ethylidene]-1-phenyl-2 thiohydantoin, was used in the standard silver bromide columns, and the developing agents were used in acetone solution to prevent chemical attack on the silver bromide. The displacement data are given in Table IV. The dye displacement is expressed in terms of percent of dye displaced per cubic centimeter of developer solution when displacement is at the maximum. The maximum displacement by acetone alone was 0.16 percent per cc.

Discussion

1-Phenyl-3-pyrazolidone can ionize in alkaline solution, according to the lactam-lactim system.[8]



The pK value is about 9 at 20 C. The non-ionized form may be nearly as active as the ion in photographic development, however. The dependence of rate upon pH is too small to be accounted for on the assumption that the ion is much more active than the neutral molecule. Moreover, the density–time of development curves show no induction period even in acid solution. The slope

of the log rate *vs.* pH curve over the pH range 5.5 to 8.5 is only about 0.3, whereas it should be about twice as great if the rate in this region were determined largely by the concentration of the ion.

The fact that the rate of development varies as about the two-thirds power of the concentration at pH 6.5 indicates that the 1-phenyl-3-pyrazolidone is adsorbed prior to the development reaction. The experimental relation is the one to be expected if the adsorption follows the Freundlich isotherm. The chromatographic experiments give direct evidence that 1-phenyl-3-pyrazolidone is adsorbed from acetone solution, and it is reasonable to suppose that the neutral molecule would be as readily adsorbed from aqueous solution.

In the interpretation of the experimental kinetics of development, two rates must be considered: (1) the rate of diffusion of the 1-phenyl-3-pyrazolidone through the gelatin layer, and (2) the rate of the chemical reaction of development. If the rate of the chemical reaction is much greater than that of diffusion, the measured rate will be that of diffusion. Conversely, if the rate of diffusion is much faster than that of the chemical reaction, the latter will largely determine the measured rate. The measured rate is largely that of the slower process. In development by 1-phenyl-3-pyrazolidone, either rate can dominate, depending on the experimental conditions.

At pH 9 and above, the development rate in the absence of added bromide varies directly as the first power of the concentration of 1-phenyl-3-pyrazolidone, and the rate is independent of pH. The development rate in this pH region is controlled to a large extent by the rate of diffusion through the gelatin layer. This conclusion is based on the following observations: The image in the early stages of development in the high pH solution is confined to the surface region of the emulsion layer, whereas it is distributed throughout the emulsion when development is carried out to the same density in solutions of lower pH. The absolute rate of development by 1-phenyl-3-pyrazolidone at pH above 9 is roughly half that by 4-amino-3-hydroxy-N-diethylaniline. It has been shown previously that the rate of development by the latter compound is diffusion-controlled[8] and the molecule of the latter should diffuse at a greater rate than 1-phenyl-3-pyrazolidone. Finally, the temperature-dependence of development by 1-phenyl-3-pyrazolidone above pH 9 is only slightly greater than that found for diffusion-controlled development by vanadous ion,[9] whereas the temperature-dependence at the lower pH values, where diffusion is not rate-controlling, is considerably greater.

The activation energy for development at pH 6.5 of heavily exposed emulsion is 12.5–14 kcal/mole. The difference of 1 to 1.5 kcal/mole between the activation energy calculated from the $1/t$ rates and the slope rates may be a consequence of the swelling of the gelatin, which occurs when the dry film is immersed in the developer. The value 12.5–14 kcal/mole probably represents the net activation energy of the chemical reaction (uncorrected for adsorption). As the exposure decreases, the measured activation energy increases to about 16 kcal/mole.

The rate of development in the lower-exposure region is determined largely by the rate of initiation of development of the individual grains,[10] and the observed increase in activation energy signifies that a greater activation energy is required to instigate development of a grain containing a relatively small latent-image center than is required to instigate development of a heavily exposed grain which contains larger latent-image centers. The activation energies calculated for the high pH developments, on the other hand, are independent of exposure, as they should be when a diffusion-controlled process masks the chemical reaction.

Addition of bromide to the developer decreased the rate of development at 20 C, even at high pH. This implies that the bromide has sufficiently slowed down the rate of the chemical reaction so that diffusion is no longer rate-controlling. The dependence of the bromide effect on temperature is in agreement with this interpretation. A bromide addition of 0.0167 *M* decreases fog, but has almost no restraining effect upon development of image at 40 C. The measured activation energy over the temperature range 30–40 C in the presence of bromide is about the same as in the absence of bromide at pH 13, and diffusion evidently is largely rate-controlling. As the temperature drops, the effect of the bromide becomes more pronounced, and the calculated activation energy increases until it reaches a value of 14, i.e., that obtained in the absence of bromide at low pH where diffusion is not an important factor. Thus, as the temperature drops, the rate of the chemical reaction becomes more and more important in determining the measured rate of development.

1-Phenyl-3-pyrazolidone and its 4-methyl and 4,4-dimethyl derivatives develop at the same rate at pH above 9. Apparently, the rate of diffusion is not significantly influenced by the addition of the methyl groups to the molecule. This is reasonable, since the size of the molecule is only slightly increased by the addition of the methyl groups. At pH 6.5, however, the development rate decreases with the addition of each methyl group. Addition of a methyl group evidently decreases the rate of the chemical reaction. It is interesting to note that the adsorption of the developer by silver bromide, as determined from the chromatographic experiments, also decreases with each additional methyl group. For these three similar compounds, at least, there is a parallel between adsorption and developer activity. No such parallel would be expected among compounds which were not similar in structure.

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TACTICAL PHOTOGRAPHY

Robert W. Barth*

TACTICAL PHOTOGRAPHY is the application of the camera in combat. More precisely, it is the camera in support of combat operations. The mission of the combat soldier is to seek out the enemy and destroy him. Tactical photography makes the task easier and less costly in terms of dollars and lives. Such photographic coverage includes troops in action, conditions under which they operate, and the results of actual contact with the enemy.

Unlike the other forms of combat photography, tactical photography seldom finds its way back beyond the field army. It has some importance at the Army and Corps levels but is designed primarily for the support of division, regiment and battalion operations, right down to the individual soldiers that are in actual contact with the enemy.

Most tactical photography is performed by the photographic section of the division signal company. These sections, consisting of one officer and fifteen men, were added to the infantry, armored, and air borne divisions after World War II giving the division commander a unit capable of handling his immediate photographic requirements. It has been these units which have been carrying the heaviest photographic loads of the Korean action and which have been exploiting the use of tactical photography.

Tactical photography is a close support of ground and aerial photography performed by the army in the combat zone for use in direct support of combat operations. It is further broken down into reconnaissance, terrain and action photography.

Tactical Aerial Photography

Aerial photography, like still and motion picture photography, can be used in all these categories. Aerial reconnaissance is a large part of the operation of Signal Corps photographic personnel in the combat zone. Aerial reconnaissance is usually photographed from an L-19 fixed-wing aircraft. The photographer opens the top half of the aircraft door and leans out to make his exposures. He uses a K-20 aerial camera, although the K-24 and K-25 have been used. He is restrained from falling out of the aircraft by a safety strap. The role of the aerial photographer in tactical photography usually begins when he receives the order to make an aerial flight. The request usually has come from the division commander or one of his staff officers through the Division Signal Officer and is given to him in the form of a target which is usually over enemy held territory. He then goes up to take pictures of the subject requested. The assignment may be one of a variety of subjects, such as troop movements, gun emplacements, or terrain suspected of harboring some unknown enemy activity. Sometimes it is a terrain study to answer questions such as: how deep is a stream? how steep are the banks of the steam? where can vehicles ford the stream? and, is there an avenue of approach and an avenue of retreat?

The pictures brought back by the aerial photographer are processed by the photographic section of the division signal company. During the Korean action, the usual procedure required an elapsed time of two hours from the time the request was issued until the finished prints were delivered.

The photographic personnel do nothing more than expose the aerial pictures, process and print them. Other trained personnel interpret and evaluate. Sometimes maps are made from the pictures by placing map coordinates and grids over them. Trained interpreters can ferret out a wealth of information from an aerial photograph which to the average eye would look like just like another picture of a piece of ground.

Sometimes the available maps of terrain which is believed to be enemy held are inadequate, containing many blank spaces. Signal Corps aerial photographers fill in these blank spaces. Often they are sent aloft to obtain "before and after" photographs of artillery targets to give the artillery soldiers a permanent record of how effective their work has been.

The pictures obtained from negatives the aerial photographer delivers are usually printed in pairs. With these pairs of pictures and suitable instruments, three dimensional stereo can be achieved.

Tactical Ground Photographs

Back on the ground, photographic personnel interpret combat pictures by the use of panoramic strips made from various ground observation posts. These strips are furnished artillery and infantry units of each command and are annotated with the names of prominent terrain features. Hill masses and stream junctions are marked and grid lines and coordinates are placed on them.

In Korea there has been no common language among the troops of different nationality under the United Nations Command. By using these panoramic strips with common, easy to pronounce names put on them (such as hill, bunker, tank and a few others) the panoramic picture briefed the combat troops and, by bridging the language barrier, made operation by the divisions more effective.

Another specific use of still photography on the ground is its use to locate hidden enemy weapons which fire on friendly positions at night. Cameras are mounted at outposts overlooking enemy terrain and the film is exposed during the day. When night falls and enemy artillery and mortar fire opens up, the shutters of the cameras are opened again. The resulting double exposures give the location of enemy fire through registered muzzle flashes

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and shows the exact positions of the weapons in relation to the terrain.

It is a common practice for a still photographer to be sent with a forward patrol into enemy territory, for he can bring back pictures of terrain and other features in the front line areas that would save many words of description. Additional information is obtained from photographs of strong points, defenses, weapons and other equipment. These pictures provide a permanent record of terrain features that are of tactical importance to the command. They are used to supplement air force, engineering, infantry and artillery material. Terrain studies magnify, clarify and pinpoint a subject. Hills, roads, equipment, troops, defenses, and other terrain which appear too small on maps or aerial photographs are shown in detail.

Equipment for Tactical Photography

Until recently, conventional press cameras were used. This equipment will soon be supplemented with newly developed 70mm military roll film camera equipment. These cameras, being lighter in weight and more durable in construction than civilian press cameras, are expected to be more suited for the job at hand.

Processing Tactical Photographs

In field processing of photographs, print drying is quite a consideration. Ferrotype tins may be stacked around the nearest tent stove or left out in the sun to dry. The film for a K-20 camera, being 20 feet long, produces problems in handling. However, two men, one on either end of the film, sometimes stretch it between them and pass it back and forth over a tent stove to dry. This, of course, is during the winter. In the summer, it is a simple matter of stretching the film between two people, wiping the water off with a windshield wiper blade, and letting the sun do the rest.

A convenient place to work in total darkness may also be a major consideration. Some photography sections are able to set up suitable facilities by utilizing whatever materials are at hand. In the meantime, the Signal Corps engineering laboratories have produced a complete, air transportable, mobile darkroom. This is called the AN/TFQ-7. This will fit into the Air Force flying box car type air-craft. It can be operated on the ground resting on its own skids and will also operate in the bed of a $2^1/_2$ ton truck.

Electrical power supply is carried along behind the mobile darkroom in the trailer hooked to the truck. This equipment is its own self-contained power plant. In service tests, the AN/TFQ-7 has been placed in operation in as little as 15 minutes. It is a completely equipped unit providing facilities for processing 35mm, 70mm, No. 120, 5 in. and $9^1/_2$ in. wide still picture roll film and 4 × 5 in. cut film and film packs. The laboratory equipped to make contact prints up to 10 × 10 in. from the film sizes mentioned and enlargements up to 8 × 10 in. from 70mm up to 5 in. film sizes. Heating and air dehumidifying units are supplied to make the equipment an all weather facility.

The laboratory shelter is an insulated structure, made of wood, fibreglass and steel. Its weight is 4,545 pounds. Normally, a four man team is required to install, operate, and maintain the equipment. The shelter is divided into three compartments separated by light-tight doors. In addition to the divided rear door, a roof escape hatch in the center compartment and a forward escape door on the road side are provided as safety measures.

The forward compartment is equipped for developing negatives and mixing chemicals. The center compartment is designed for contact and projection printing. Prints to be washed pass through a light-tight recess to the rear compartment which contains the equipment for washing and drying prints and film. This compartment also contains an ion-exchange water conditioner for water purification. All compartments have cabinets and drawers to store chemicals, film, paper and small equipment components.

The built-in water supply system consists of a 50 gallon storage tank with necessary tubing and pumps to circulate the water through the three compartments. When available, fresh water may be pumped into the laboratory through a 50 ft. length of hose from a stream or other outside source. Water contaminated by the photographic process may be recirculated through the ion-exchange unit to be purified and returned to the water storage system

This new mobile darkroom, plus the new stabilization process which utilized thiourea and water resistant photographic paper, cuts the processing time to a matter of seconds and eliminates washing and enables the Signal Corps to provide prints to front line units within a matter of minutes after the negatives have been exposed, when this action is necessary.

Photographic Organization in the Army

In a Theatre of Operations there are Photographic Sections operational at the Theatre, the Army, the Corps, and the Division level. These units are responsible for a major part of the Signal Corps photographic coverage. In the case of the Infantry Division, the Division Signal Company, expanded after World War II to add the sixteen people, as mentioned earlier, are responsible to the Division Commander for any photographic support he or his staff may require. They "belong" in every sense of the word, the same as any other group of soldiers in the Division, whether they be artillery, armored, quartermaster, or infantry. The Division Signal Company is not sent from some other outfit for duty with the Division. Its members wear the shoulder patch and are part and parcel members of the combat team the army calls a Division.

Tactical photography, which began with Brady over 90 years ago, has reached its present degree of perfection. Developments in equipment, processes, and techniques enable the United States Army to utilize photography as a vital weapon in direct support of combat operations.

A REFERENCE SCALE FOR HYPO DETERMINATION IN FILM WITH ACID SILVER NITRATE

R. W. Henn and J. I. Crabtree*

THE SILVER NITRATE, spot-testing solution for determining residual hypo (Kodak HT-2) has been applied semiquantitatively to papers by the aid of printed patches[†] but the reference patches are not applicable to the determination of hypo in film.

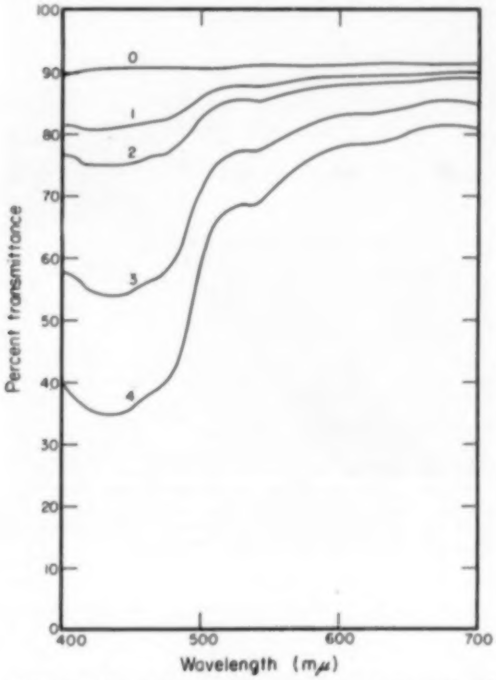


Fig. 1. Spectral absorption curves of the printed comparison patches. Curve O applies to the clear base, curves 1-4 to the imprinted squares, corresponding approximately to the stain left by 0.005, 0.01, 0.04, and 0.10 mg. of anhydrous hypo per square inch. The exact magnitude of the absorption in the blue end of the spectrum is not as important in characterizing these patches as the over-all density level.

The quantitative procedure currently recommended for the determination of hypo in films is the mercuric bromide test of Crabtree and Ross, as detailed in the Proposed American Standard Method for Determining the Thiosulfate Content of Processed Photographic Film (PH4.8). This test is very sensitive, especially when followed with photoelectrical equipment, but requires either such an opacimeter or the preparation of a set of comparison standards with each determination.

* Research Laboratories, Eastman Kodak Company, Rochester 4, New York. Received 7 May, 1954.

† Eastman Kodak Co. leaflet "Permanence of Photographic Negatives and Prints," Rochester, N. Y., 1952.

It has been considered desirable therefore to reduce the more easily applied silver nitrate test to a quantitative basis for films as well as for papers.

The successful achievement of this end has been due in considerable part to the development of a "brown scale," printed by a halftone process on cellulose acetate sheets. The densities of the patches run the range from that produced by the hypo left after moderately successful commercial washing to that of archival washing of fine-grain materials (0.005 mg. per square inch) (Figure 1). The scale colors have been found stable to normal exposures to light but will fade gradually on prolonged exposure to direct sunlight.

Hypo may be retained in both (a) the emulsion, and (b) the backing of gelatin-backed films. That retained in the emulsion side is often greater in quantity and is, obviously, more important for permanence.

By applying the test solution to both sides of the film so that the spots are superimposed, the total hypo is determined as in the mercuric chloride test but, for the sake of simplicity and to avoid the time involved in drying, the test may be made by spotting only the emulsion side.

KODAK HYPO TEST SOLUTION HT-2

	Avoirdupois U. S. Liquid	Metric
Water	24 ounces	750.0 cc.
*Kodak Acetic Acid, 28%	4 ounces	125.0 cc.
Kodak Silver Nitrate	1/4 ounce	7.5 grams
Water to make	32 ounces	1.0 liter

* To make approximately 28% acetic acid from glacial acetic acid, dilute 3 parts of glacial acetic acid with 8 parts of water.

Store in a screw-cap or glass-stoppered brown bottle away from strong light. Avoid contact of test solution with the hands, clothing, negatives, prints, or undeveloped photographic materials; otherwise black stains will ultimately result.

Making the Test

The test is most quantitative when applied to dried film containing an appreciable unexposed area. It may be applied to damp film (with excess moisture blotted off) or to a small clear area with somewhat reduced accuracy.

Place one drop of the HT-2 test solution on the emulsion side of the processed film. Allow it to stand for two minutes. Blot off the excess reagent and compare with the printed scale in diffuse daylight. When making the comparison, place the spotted film over the scale in such a way that both the test and the comparison are viewed through the thickness of both film bases to compensate for hue and density introduced in the film itself (Figure 2). When viewing, hold the crossed films a little distance from a white reflecting surface or over an appropriate illuminator. Tungsten light may be employed but will somewhat reduce the sensitivity

Table I

TOLERABLE HYPO CONTENT IN FILMS

Material	Type of Use	Tolerable Hypo Content* (Mg. per Sq. Inch)	Corresponding Patch
Fine-Grain (Positive and Microfile)	Archival	0.005	No. 1
Fine-Grain (single-coated)	Commercial	0.02-0.04	Nos. 2 to 3
Coarse-Grain (most commercial, roll, and x-ray films) (double-coated)	Archival	0.02-0.04	Nos. 2 to 3
	Commercial	0.10	No. 4

* Anhydrous $Na_2S_2O_3$. Content of emulsion side only. Hypo contents of double-coated films as determined by the mercuric chloride test are often double these values.

of the test. Direct sunlight is to be avoided, as it will cause the spot to darken rapidly. If there is doubt with regard to uniformity of washing, the film may be spotted in several areas and also on the back. In any case, these areas must be waste (as in the margins) and should be discarded after spotting.

Interpretation of Results

The patches have been calibrated by comparison with the mercuric chloride test as follows: No. 1, 0.005; No. 2, 0.01; No. 3, 0.04; and No. 4, 0.10 milligram of hypo (anhydrous) per square inch.

The tolerable hypo content in films (emulsion side only) based on our present state of knowledge, is given below. These values are, in general, somewhat more conservative than those given by Crabtree, Eaton, and Muehler,* but they are based on anhydrous rather than crystalline hypo. Also, recent improvements in washing aids make attainment of low hypo levels much easier.

These data are given for permissible quantities of hypo in one side (emulsion) of the film. In the case of films with emulsion on both sides, the permissible quantity (total front and back) will be double these values but somewhat less than double in the case of gelatin-backed films. Repeated spot tests of the gelatin backing will indicate the relative significance of its hypo content in relation to that of the emulsion coating.

* "The Removal of Hypo and Silver Salts from Photographic Materials as Affected by the Composition of the Processing Solutions," J. I. Crabtree, G. T. Eaton, and L. E. Muehler, J. Soc. Mot. Pict. Eng. Vol. 41, July 1943, pages 9-68.

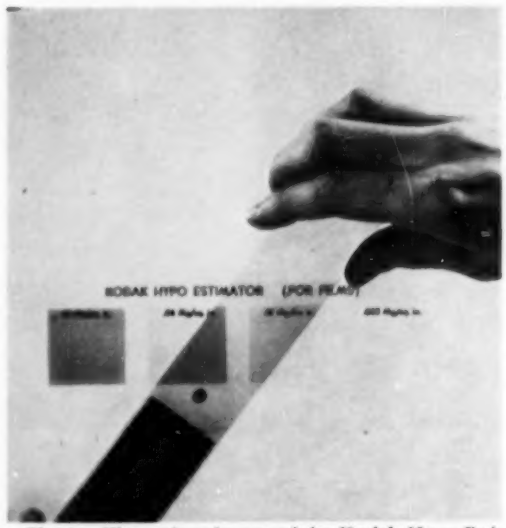


Fig. 2. Illustrating the use of the Kodak Hypo Estimator. Note that the films have been so crossed that both the spotted area and the imprinted patch are viewed through the density of the two film bases.

MODERN STEREO TECHNIQUES

Joseph Mahler*

STEREO techniques today can be divided into three groups. The first group is the one which utilizes all the innovations of photography and presents the results with the help of optically improved Brewster and Wheatstone Stereoscopes.

The second group is concerned mainly with new stereo techniques achieved with polarized light which lends itself so remarkably well to stereoscopic advancement.

Finally, the third group deals with free vision stereoscopy, using mostly grid, lenticulated screen or other lens methods in order to "direct" the light beam.

The group which uses the Brewster stereoscope still represents the majority in the field of stereoscopy. Orthostereoscopy would be a better term because today's stereo viewers, using the same focal length as the taking camera, do achieve rather good orthostereoscopic results, which is the ideal of three-dimensional presentations. The Stereoscopic Committee of the Society of Motion Picture and Television Engineers proposed a wording for the nomenclature on orthostereoscopy as follows: "Orthostereoscopic image is an image appearing to the observer as having the same size and shape and

* American Optical Company Research Center, Southbridge, Massachusetts. Presented 17 December 1953 to th PSA Technical Division Section at Cornell University, Ithaca, New York. Received 5 June 1954.

being at the same distance as the original object was from the camera." This means to maintain the angular size and the convergent angle.

The innovations in photography, like color film, high speed and fine grain photographic emulsions, etc., are the tools with which modern stereo technique creates slides for direct viewing and projection. The future trend in stereophotography, which may be realized in not too distant a time may be outlined as follows.

A projected wide angle picture on a very large curved screen, if seen from a proper distance, will appear to the observer as though he or she would be in the picture itself, rather than merely looking at a picture. This effect, together with color and the third dimension can doubtlessly be recreated not only by a motion picture projection, but also with some special new wide angle stereo camera and a new Brewster stereoscope specially designed for this purpose. The design of such a camera and viewer will not be an easy task. However, some genius in optics probably can solve this problem and will. It certainly would be nice to gaze into such a modern stereoscope, not merely to see a stereo window but to get the feeling of participation in the scene itself.

Polarized Light Applied to Stereo

Rather than the Brewster viewing type of stereoscope, the main feature of this paper is polarized light, as it is used for stereoscopy. Unfortunately, not too many stereo amateurs really understand the theories and physical construction of polarizers, polarizing pictures called Vectographs, and also, they perhaps do not quite realize the tremendous potentialities that polarized light holds in the stereo field.

There are two existing categories. The one which uses ordinary transparencies needs a projection system, where *two* polarizing filters *must* be placed within the light path and their axes of polarization must be positioned 90° to each other. The other category uses transparencies which have been made from polarizing substances and do not require any polarizing filters in the projector, whatsoever.

Ordinary light, coming from sources such as the sun, an electric bulb, etc., vibrates in all directions at right angles to the direction of travel. These light vibrations can be readily combed or arranged into one plane only with the help of two distinctly different systems—the one system is very simple. The light which is reflected from non-metallic surfaces such as glass plates, water surface, glossy lacquered surface, etc., and being at an angle of approximately 33° from a glass surface and 37° from a water surface depending on the refractive index, is plane polarized, having its vibrations horizontal to the surface. This type of polarization is of no value to stereoscopy.

Polarized light, however, obtained by selective absorption of light within certain dichroic crystals, appears of utmost importance to stereoscopy. It is useful both in the sheet polarizer and the polarizing pictures called vectographs because both are needed for the stereo art, especially for future use.

First, what is a dichroic crystal? A crystal is called dichroic if the light which passes through is treated as two components, whereby the transmitted component is polarized in vertical plane, while the other component vibrating horizontally is fully absorbed.

Such crystals are found in nature and the best known is the semi-precious uniaxial crystal called "Tourmaline." The first synthetic polarizing crystal was accidentally discovered by a Mr. Phelps, who was a pupil of Dr. Herapath of Bristol in the year 1854, just 100 years ago. This crystal was made from iodine and quinine bisulphate and received its name after Dr. Herapath. Unfortunately, these herapathite macro crystals had a rectangular shape and therefore it was technically impractical, if not impossible, to form a large area in order to produce a sheet polarizer.

Eighty years later, in 1934, Edwin H. Land, at that time a Harvard student and now president of Polaroid Corporation, conceived the idea to precipitate such herapathite crystals in the form of microscopically minute needle-shaped crystals and embedded them into a plastic flowable mass. These crystals readily oriented themselves when the plastic was extruded through a narrow slot and set hard to a film. This polarizing film was known as "J" type and the patents expired two years ago.

Disadvantages inherent in the described polarizers have been many. First, the films have shown some haziness because the size of the embedded crystals often exceeded one micron. In addition, there was insufficient stability of such polarizers and then the production was not too simple, with one exception as follows:

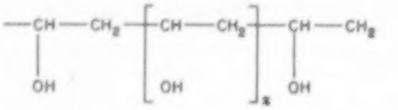
It has been found that the needle-like crystals embedded in plastic can also be readily oriented by a smear technique with the help of a metal or glass doctor blade. This method was used by the writer in Europe in the year 1936 to produce polarizers. The fact that such crystals when unprotected could easily be destroyed led fortunately to relatively easy reduction to practice of polarizing pictures. The first polarizing picture was made by the writer on September 26, 1937 in the most primitive manner.

The oriented crystals were smeared on a rigid gelatin film surface and protected with a very thin layer of wax. Then a metal half-tone plate, such as is used to print pictures in a newspaper, was warmed up enough to emboss the half-tone plate dots into the wax layer. When the film was later exposed to ammonia vapors, the embossed and unprotected portions of the crystals were destroyed, while the protected portions were retained and a polarizing image was born. Two such pictures stereoscopically taken and with their axes of polarization superposed 90° to each other could be viewed three-dimensionally with properly oriented polarizing filters. Polarizing analyzers or viewers are of course always an integral part of such systems.

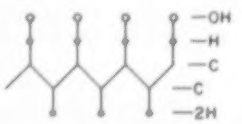
The main advantage and strength of the vectograph lies in the fixed, superposed and controlled position of a stereo pair within the slide or film. All this is done prior to their projection and is carefully prepared at the time when the slide or film was manufactured. Such a stereoslide also requires only a one-lens standard projector. The advantage over the method where a stereo pair must be separately projected is so great that, for instance, the 3-D motion pictures of recent months became questionable simply because the audience cannot be constantly punished by the vast errors such as

strong vertical displacements of the stereo pair and different stereo pair illumination, different focus, etc

Drastic improvements in the quality of polarizers and vectographs occurred in 1940 when Dr. Land found that polyvinyl alcohol film is a suitable basic material for the production of sheet polarizers, the way we know them today. For the first time, both neutral and color polarizers and black-white and color polarizing pictures could be made. The chemical formula of polyvinyl alcohol is—



and for the oriented polyvinyl alcohol, Dr. Land's favored schematic interpretation looks like this:



The orientation of the molecules of the polyvinyl alcohol film is done exclusively by stretching techniques using either heat to soften the film or rendering the film, by water and salts, rubberlike.

The oriented or stretched film alone, of course, does not polarize but when the dichroic crystals, this time in molecular form, are electro-chemically bonded to the oriented molecules of polyvinyl alcohol, a sheet polarizer will result. Iodine will produce a neutral polarizer called "H" type, while dyes of dichroic nature will make any desired shade and are known as "L" type. Polarizing pictures are made with both types. Finally there exists another polarizer called "K" film. This is the most stable and efficient polarizer and best suited for the automobile headlight project, about which you have doubtlessly read. This polarizer is also used for stereo projectors of any type because it will withstand the heat involved.

Here, no dichroic crystal molecules are used. Instead, a catalyst such as hydrochloric acid is added to the polyvinyl alcohol film and with higher heat and stretch, the polyvinyl alcohol will change to polyvinylene—(—CH=CH—)

which probably is a conjugated dehydrated polyene structure not quite yet understood.

Having discussed the basic theories on today's polarizers, it is necessary to explain in a simple manner just what a polarizing image is, as coined by Dr. Land, "The Vectograph."

Ordinary photographic pictures or transparencies in black and white are formed from reduced silver deposits and, in case of color, from dye deposits. Where there is a deep shadow, quantitatively, most of the silver particles or dyes exist. In vectographs, all that is needed is to replace the mentioned deposits with *dichroic* stains or *dichroic* dye deposits, and instead of forming the pictures in a gelatin base which is *isotropic*, we make the vectographic print in an oriented polyvinyl alcohol base which is *birefringent*. Where most of the dichroic stain is deposited, the darkest polarizing stain will be obtained and no polarization will exist in the highlights because there are no polarizing deposits at all.

Figure one shows a superposed vectographically printed stereo picture and how it is controlled by an analyzer.

Triangle "L" represents the deepest shadow of the left eye polarizing picture of a stereo pair. This is printed on the front surface of a vectograph film, which is oriented from left to right. On the back surface of a vectograph film, which is oriented from right to left at 90° to each other, the right eye (Triangle "R") polarizing stereo pair picture has been printed. Because the axes of polarization of the stereo pair are 90° to each other, the light will permanently not pass through the crossed areas.

If a polarizer, in this case one has to call it an analyzer, is placed over such print, with the same axis of polarization as the left eye stereo pair picture, the portion marked with arrow "L" will disappear, because the analyzer will equalize the densities between the highlight marked 100% and shadow marked 40%.

Simultaneously, the same axis of polarization of the analyzer will cross with the axis of polarization of the printed portion marked arrow "R." This portion becomes dark and the whole triangle "R" becomes visible.

Analyzer in contrary direction will make visible the triangle "L" of course. That is how 3-D glasses make certain that each eye sees only its own stereo pair picture in a vectograph.

Free Vision Stereoscopy

The third group deals with free vision stereoscopy. This is the most desired stereoscopy, but technically and optically, the most difficult one.

No practical solution appears on the horizon for free vision projection. Such systems as proposed by the Russian scientist Ivanov or Mattey in Paris confirm only the complexity of this problem. At this point it should be explained why it is so. To see true stereo, the left eye must observe a different perspective image than the right eye. The brain fuses these two views into a three-dimensional one. But this is not all. The left eye must have on its retina a perspective image which was photo-

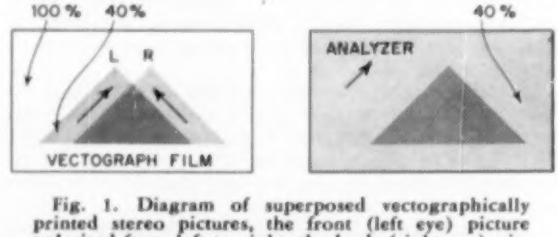


Fig. 1. Diagram of superposed vectographically printed stereo pictures, the front (left eye) picture polarized from left to right, the back (right eye) picture polarized from right to left, with the axes of polarization crossing at 90°.

graphed from the left standpoint of view; and the right eye, from the right standpoint of view because otherwise, a pseudoscopic effect is inevitable.

In nature, to a person moving from left to right or vice versa, an infinite number of different perspective image will appear on the retinas of both eyes in the manner just explained. If we want freedom of movement in stereo projection as it is in nature, all these infinite perspective views would have to be projected on, and also properly reflected from, a lenticulated screen. This is the crux of the issue.

Some positive results of free vision stereoscopy are those made by a lenticulated photographic film. Kanolt, as first, in 1915 called it parallax panoramagram; later, Bonnet, Winnek and others used such photographic film which had fine cylindrical embossed lenses about 100–300 to an inch. And beyond each cylindrical lens, twenty or more different perspective views in a line form of a scene have been photographically recorded by scanning around the object or scene with a camera having a special large lens and a moving diaphragm. The greater the number of perspective views chosen to be in "line form" registered beyond these fine lenses, the more definition and quality of course were lost, and because of this, the resulting pictures are of a limited nature. Closeups remain as the most feasible approach and stereo pictures of this type are only occasionally seen as a display in showcases. They are also rather expensive.

A free vision viewer, but again only of a limited nature, has been made by the writer. A crude optical bench-type model may be assembled to demonstrate the result. This true stereo viewer uses directional light source, see Figure two.

In front of a light source is placed an opal or ground glass plate which is divided into two halves. One half is opaque; the other is translucent. See Figure two.

Then a condenser is placed in front of the plate, approximately a distance of its focal length, plus one-third. Then a black-white but preferably color transparency is located in front of the condenser. The observer will notice that the picture becomes fully illuminated only to his left eye, but if one reverses the position of the split field plate, then only the right eye would see the picture.

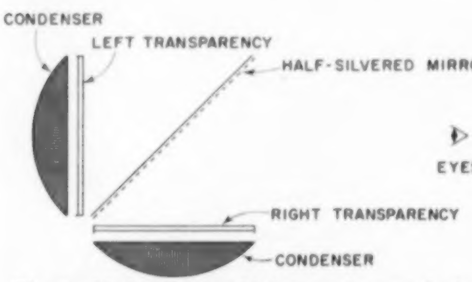


Fig. 3. Method for combining two images obtained as shown in Fig. 2 to provide free vision stereo viewing.

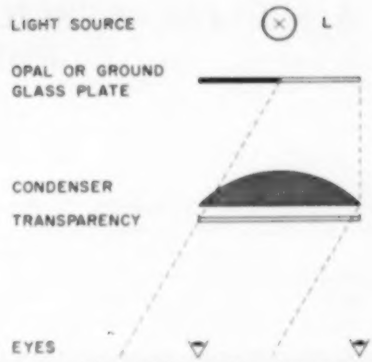


Fig. 2. Top view of free vision viewer component showing opal or ground glass with one half opaque, transmitting an image mainly to one eye.

Based on this fact, the viewer looks as follows: The left eye stereogram transparency is set vertically and the right eye stereogram transparency is set horizontally, each 90° to the other. In between, at 45°, a half-silvered mirror is positioned so that the observer actually can see both stereo pictures superposed if both pictures are normally illuminated. The next step is to bring the two condensers behind the two stereo-transparencies. See Figure Three.

By bringing the two split field opal glass plates to a 90° position and with the help of two mirrors, only one light source is needed to complete the viewer. (Figure four). If so desired, but it is not essential, a front lens can be used to magnify the picture and, of course, the viewer can be encased.

A simpler viewer called "Vectoscope" is shown in Figure one, only that the plate is made from two polarizers called split field polarizers, each field having its axis of polarization 90° to each other, and instead of using ordinary transparencies, one must use vectographs.

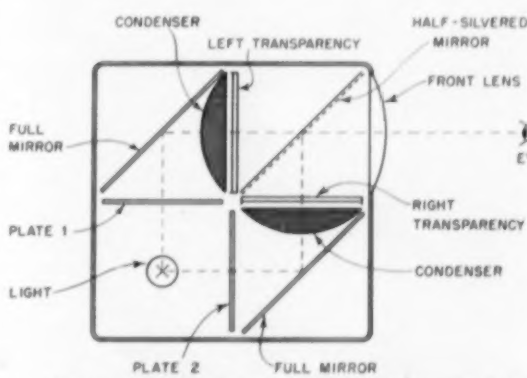


Fig. 4. Complete free vision stereo viewer. By using mirrors, a single light source illuminates both the left eye and the right eye transparency through half-opaque diffusing glass oriented 90° apart. A front lens is shown to magnify the resulting stereo image.

A SPECIAL APPLICATION OF POLARIZATION PHOTOGRAPHY

H. Lou Gibson, FPSA

THE STRAIGHTFORWARD techniques of photography with polarizing filters are of well-known usefulness. Nevertheless, by the application of fundamental principles, unusual applications of photography by means of polarized light can often be discovered. And this, of course, is true of most technical photographic methods.

A good representation of the visual appearance of a $^3/_4$-inch square piece of smaltite is shown in Figure one. The specimen has a polished flat surface and is seen obliquely here. The cobalt mineral is embedded in a milky matrix with black veins. Notice the two distinct characteristic patinas of the metallic components—

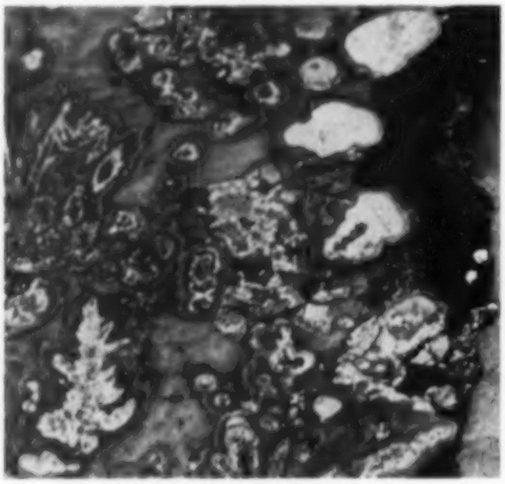


Figure 1

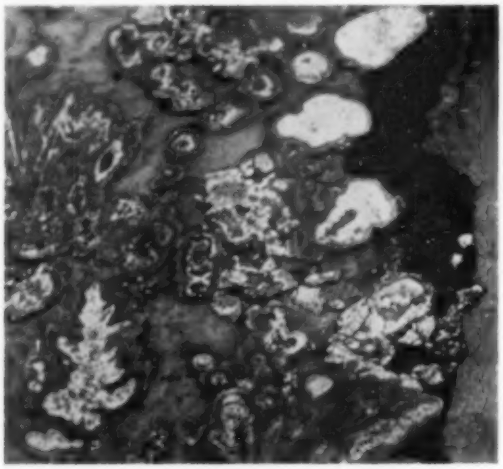


Figure 4

Figure 2

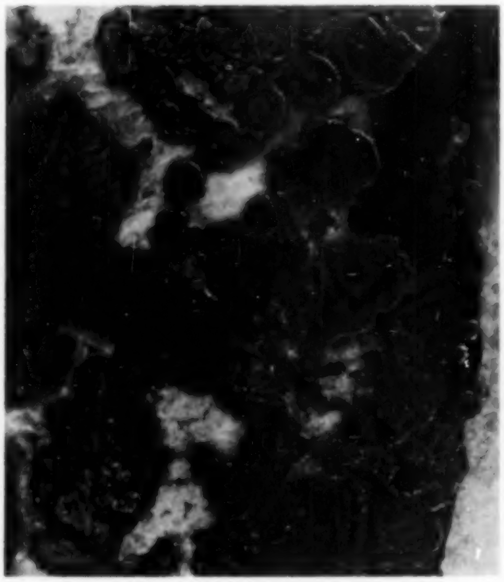


Figure 3

the mirror-like round pools and "Xmas trees," and the dull, leaden grey margins to these areas.

Orthodox photographic methods failed to distinguish the four significant features: (1) milky white matrix, (2) black vein, (3) shiny "metal" and (4) dull "metal." The perpendicular view in Figure two shows the first approach. Since the specimen was flat and polished, the usual "copy lighting" for such surfaces was tried. The result is that the "mirrors" did not reflect any light into the lens because the 45-degree angle lighting is designed to prevent specular reflections. These mirrors then were merely reflecting the dark ceiling above the camera. The result was that the mirrors and the black vein became indistinguishable.

It is obvious that bringing the lights close to the camera for the purpose of obtaining specular high lights from the mirrors would also cause reflections of the lights in the other shiny surfaces. However, white "cages" made from blotters are often used for photographing silverware. The adoption of this measure was the logical step; the result is shown in Figure three. Notice that the mirrors have become brightened—but so has the black vein. There is also a general lack of contrast in the photograph.

It was obvious that a different approach would be needed with this specimen. Accordingly, the piece was illuminated with a single flood light directed at an angle of 35° to the horizontal surface. The camera was placed directly opposite this light, also at a 35° obliquity. This resulted in the full glare off the surface being directed into the lens. (Direct light from the lamp was shielded from the camera.) Figure four shows how the subject was recorded under such conditions; it was printed on a contrasty paper to offset the low contrast caused by flare. Yet notice the "grayness" of the vein.

To obtain the result shown in Figure one, the same setup was maintained. However, a polarizing filter over the camera lens was oriented so as to subdue the strongly polarized glare—polarized by reflection, not by another filter. The glare from the highly metallic mirrors was, of course, hardly polarized at all, therefore it persisted. The matrix and vein were non-conducters and thus they polarized the reflections, which made them tractable with respect to subduing glare. The dull margins also produced some polarization, but held their medium tone largely because of the intrinsically lower glare from their bloom.

At first glance, it may be thought that polarizing filters over lights and lens might have offered an answer. Such a scheme would have produced a *polarized* reflection from the mirrors. This would have been unserviceable. The solution to the separation of the four areas depended upon the fact that the reflected glare from the metallic mirrors was *unpolarized* while the balance of the glare was vulnerable to reduction with a polarizing filter.

STANDARDIZATION IN PHOTOGRAPHY

Ira B. Current, APSA*

Like any other craft having universal application, many aspects of photography require standardization in order to permit interchange of the various components and techniques. Through standardization it is possible for photographers in all parts of the world to make pictures with various types of equipment and with all kinds of materials, all with a minimum of experimentation to "zero in" on a photographic project.

This paper will discuss only a few of the multitude of aspects of photography that have been standardized internationally, nationally, or by one or more manufacturers. It will also try to point out where internal standardization by the manufacturer makes it possible for him to deliver products that will meet the exacting requirements of the photographic trade.

In the field already existing standards make it possible for the various manufacturers to produce sensitized materials that are physically and dimensionally suitable to many makes of cameras, and which guide the camera manufacturers to make equipment that will accept the sensitized materials. Other standards provide a common basis for proper exposure of the sensitized materials on the basis of an exposure index value that is assigned to the material. A listing of such standards has been issued by the American Standards Association, Incorporated, 70 East Forty-fifth Street, New York 17, N. Y. There are some 240 standards covering photography and cinematography. The subjects range from dimensions of films and film holders, through sensitivity characteristics, to chemicals used in photographic processing. These standards have been carefully prepared through cooperation of manufacturers, consumers, and scientific bodies. They may be purchased at a nominal cost from the ASA, and a few of them are indispensable aid to any serious photographer. Some professionals or scientific photographers whose activities cover a wide field may find that they require a complete set of these American Standards for photography.

Standard Film Speed

Perhaps the question that comes to a photographer's mind first is the one of speed of the sensitized material he intends to use. American Standard Z 38.2.1-1950,

* Ansco Division, Binghamton, New York. Presented 19 November, 1953 to the PSA Technical Division Section at Cornell University, Ithaca, New York. Received 5 June, 1954.

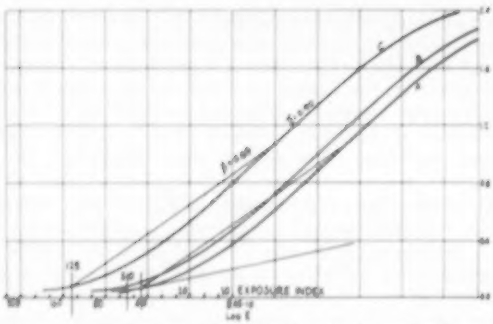


Fig. 1. Derivation of standard ASA film speeds and exposure indexes for three films. Curve A represents a film for which the 0.3 fractional gradient point falls within the range denoting ASA exposure index 40. Curves B and C show films of progressively greater sensitivity falling in the exposure index ranges 50 and 125 respectively.

"American Standard Method for Determining Photographic Speed and Exposure Index,"† covers a precise method of determining the speed and Exposure Index of (a) a specific sample, and (b) a product. Another American Standard, Z 38.2.2-1949 constitutes a "Photographic Exposure Computer," and consists of a small booklet listing light index tables, and exposure index tables along with a dial calculator for computing the camera exposure. Based on tests made in accordance with the first standard, where it is applicable, the manufacturers assign exposure index values to their products, which may be used in conjunction with the computer. The ASA values are also applicable to exposure meters and calculators calibrated in terms of ASA exposure indexes. In cases where the film speed standard does not apply, such as high contrast films, color materials, etc., the exposure index values are assigned by the manufacturers of the product on the basis of many precise practical tests, and laboratory sensitometry.

Calibrations on the base line of Figure one mark exposure ranges that correspond to the ASA Exposure Index values. Each value represents an exposure range of $^1/_3$ lens stop. If a film manufacturer's tests were always precise, he could measure the response of the films to light, and determine whether or not they fit within these exposure index ranges. However, in conducting the tests themselves, there are many sources of variation such as small fluctuations in illumination from the exposing lamp, variations in sensitivity because of the ambient humidity, small processing variables in time, temperature, agitation, chemical composition, and small variations introduced in densitometry. It is occasionally possible for all of these variables to add together algebraically to give a result quite far from the correct one. In most cases, the results on a given sample would group themselves in a statistical pattern represented by a normal distribution curve. Since it is very difficult to hold the speed tolerance of the film itself within this $^1/_3$ stop range, most of this range, and sometimes more, will have to be applied to the material at the time of manufacture. Actually, aging, under various conditions of temperature, and humidity will add to the variation. All these tolerances, in turn can result in quite a wide range of values, again falling under a normal distribution curve, when making measurements of the speed of a given product. The manufacturer does hold the product average to the center of the assigned exposure index tolerance, but all of the variables enumerated above may give a range represented by the scatter plot of values determined for two products having the same speed as shown in Figure two. Figure three shows a frequency plot of the scattered values that have been plotted in Figure two.

The formal data for sensitized products, tend to represent the maximum capabilities of the emulsions. These maxima are seldom reached in practice because of developer formulas chosen for finer than normal grain, lower contrast, etc. Thus, a part of the safety factor is accounted for.

Many photographers make use of an exposure meter to measure the light values in the scene they are about to photograph. (If the computer is used, the light index values are judged and selected by use of the descriptions given in the computer tables.) A great deal of judgment

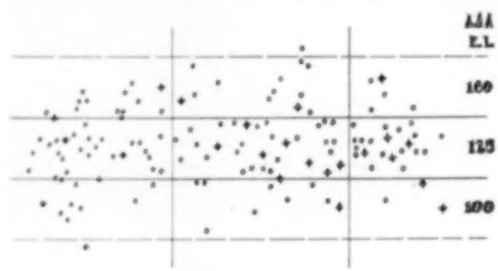


Fig. 2. ASA exposure indexes determined over a period of years for individual samples of film products from two manufacturers, both having an assigned exposure index of 125. While most of the determinations fall within the 125 exposure index range, a scattered few fall in the 100 range and others fall in the 160 range.

is required in using an exposure meter. If a large amount of sky is included in "reflected light" measurements, the foreground will be in disfavor and not receive enough exposure after the computations are made. On the other hand, if the meter is pointed to a dark area, a tendency to overexpose brightly illuminated parts will occur. There are many ramifications of scene brightness distributions between these two examples. The judgment factor must be included in exposure calculations.

The exposure meters themselves, cannot all be made exactly alike. There must be some tolerances, just as in the manufacture of film, so this is also added to the judgment factor.

There are many types of lens construction with varying numbers of air-to-glass surfaces each of which remove part of the light. Sometimes all or part of the surfaces are anti-reflection coated. A lens may transmit anywhere from about 60% of the light to about 95%. Shutters are even more inclined to vary. Between-the-lens shutters may give exposures from about $^1/_{20}$

† Based on This American Standard, an International Recommendation (ISO/R 6) "Method for Determining Photographic Speed and Exposure Index" was approved for international adoption by The International Organization for Standardization (ISO) by correspondence vote of its Council in Geneva effective 21 May, 1954. [Ed.]

to $^1/_{60}$ of a second when the indicator is set at $^1/_{25}$ second. Most of them become even less accurate at higher speeds, and the effective exposure is even further modified by the shutter efficiency, or the time it takes for the shutter to open and close.

The top distribution curve in Figure four represents the speed measurements of a particular sort of photographic film. The second curve represents the exposure meter sensitivity variation, with a dotted outline showing the additive results of the meter sensitivity and the film sensitivity variation. Next is the lens variable curve, and below that the shutter variable curve. The bottom curve represents the exposure range that might be the correct one for a large group of exposure meter-camera combinations with the given film.

This illustration summarizes the need for a "safety factor" in the exposure index value, and at the same time illustrates the kind of philosophy that has to be applied in any kind of photographic standardization. This philosphy is not unique to the photographic craft but is universal. As many people know, even measurements of nuts and bolts from a given machine will not be uniform, and a large number of measurements will provide a range of values with the largest number being near the center of the range. Various classes of fits will have different ranges.

In subtractive color photography, the possibility for variation from an acceptable result is multiplied by the three layers that contribute to the picture. Not only must the speed of the three layers be properly balanced, but also the conformity of the curves throughout their scales must be such as to provide an acceptable rendition of gray. This greatly increases the complexity of manufacture and processing of color photography materials. Added to the usual black-and-white sources of variation is a color rendition variable in the quality of the light used to expose the film. Nevertheless, materials are released having speeds that fall in a normal distribution pattern with limits that are $^1/_3$ stop above and below the nominal value. Color balance is maintained within a range that would permit a similar deviation of a "3" series filter from neutral (Density of about 0.07).

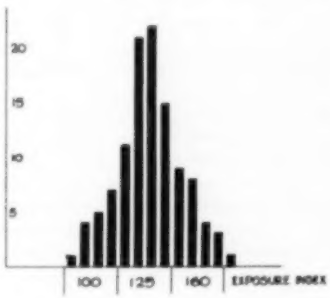


Fig. 3. Frequency distribution of the exposure index values given in Fig. 2. The preponderance of 125 exposure index values is clearly shown.

Amateur Camera Standards

Millions of box cameras are manufactured every year. These do not find their way into use by professional photographers. Instead they are the "peoples" cameras and the final report as to performance merely states that the pictures are "good" or they are "not clear." These

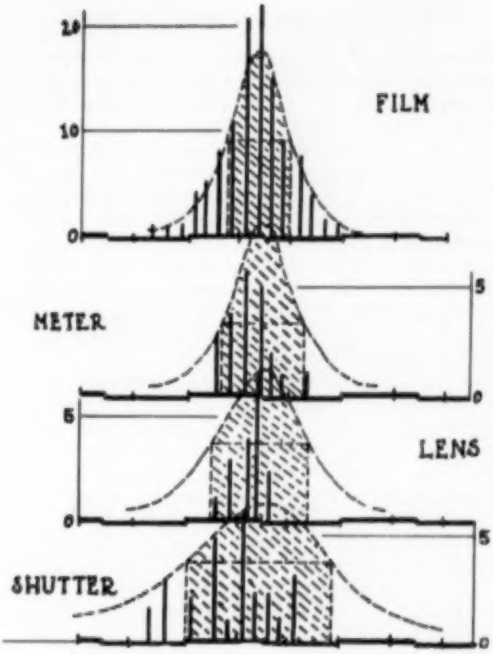


Fig. 4. Cumulative effect of film exposure index variables from random samples, variables introduced by a collection of photoelectric exposure meters, by lens transmission and diaphragm calibration variables; all superimposed, in the bottom figure, on variables in exposure timing introduced by camera shutters.

amateurs usually are not able to put their finger on the cause for poor pictures. They cannot tell camera movement from out-of-focus, underexposure from overexposure. For the manufacturer to get a favorable judgment on his product, he must anticipate the kind of pictures the photographer is going to make.

Among many other considerations is one concerning the object plane the fixed-focus lens of the box camera should be set to focus on. Should the lens be set to take pictures at infinity, or should they be sharp at five feet? At the present state of the lens art, both conditions cannot be met without a supplementary lens. An analysis of 1456 randomly selected photographs from a photo finishing line showed that the breakdown of principal object distances was a follows:

Percent of Pictures	Object Distances from Camera
41%	50 feet to infinity
31%	15 feet to 50 feet
23%	8 feet to 15 feet
5%	closer than 8 feet

It was observed that pictures of people were usually made at a distance of 9 to 20 feet, with the greatest number at 13 to 15 feet. The conclusion was reached that the box camera setting should be set such as to insure that "infinity" pictures would be just acceptably sharp. The depth of focus of this type of lens will then permit sharp pictures at distances of 7 or 8 feet.

Physical Characteristics of Films

Dimensions of photographic materials have to be standardized in order that they will fit into the multitude of camera designs that exist or are even now only at the planning stage. The tolerances must never give interference, for even one sheet of film too thick to fit into a holder cannot be accepted. However, the question is not always one of a simple dimension, but involves also the shape of the film. If a sheet film has a slight curl away from the emulsion side, it interferes with the shape of the grooves in the film sheath and cannot be inserted in the holder. The conclusion may be reached that the film is too thick, but actually non-standard curl is the problem. Unexposed sheet film should be flat, or have a slight curl toward the emulsion side.

The curl characteristics of the sensitized materials are measured and controlled. Figure five shows a film curl testing device. Specimens of the film materials, cut to proper size, are inserted into these miniature curl cells. The whole is placed in a controlled humidity cabinet for a period of time, and the curvature of the film measured by noting the line to which the shape of the film most nearly conforms. The curl value, which is 100/radius of curvature in inches is higher for greater curl, a value of 0 representing a flat film. In practice a statistical evaluation and limits may be established for the film curl evaluation process.

Like these examples, all of the many characteristics of photographic materials have to be measured and

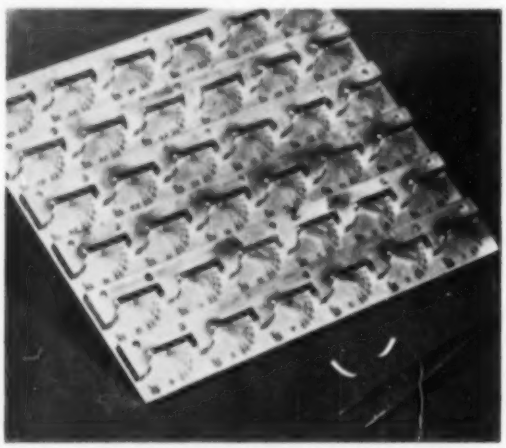


Fig. 5. Film curl measuring cells calibrated with curl charts which yield numerical values for curl of the 4mm × 16mm specimens that have been cut both parallel to and across the machine direction. Such "curl boards" may be placed in a variety of humidity conditions for standard evaluation of film curl characteristics.

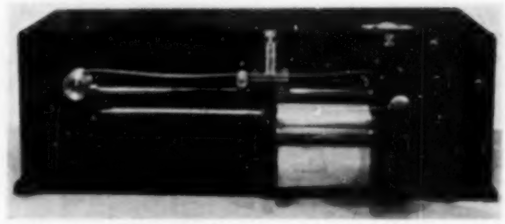


Fig. 6. Standardization of surface friction characteristics of 16mm motion picture films is facilitated by the use of devices such as this one. The instrument measures and records the tension required to pull a film sample through a simulated film gate at which pressure on the film can be varied by loading with weights of different value such as those shown above the pressure plate in the illustration.

standardized. A few additional measuring instruments used for this kind of work include the following:

Tensile strength testers, brittleness evaluators, film friction testers, shrinkage gauges, abrasion sensitivity testers, resolution charts, spectral sensitivity instruments, and color (spectrophotometer) analyzers.

Within photographic manufacturing plants tremendous testing programs are constantly in motion to insure that all of the materials produced are capable of the finest possible results. However, sensitized materials, and the photographic equipment with which they are used, do not now lend themselves to the precision found, for example in the mechanical trades, for the price that the ordinary consumers can afford. (Precision equipment and calibration of sensitivities, etc. is possible, and is used in manufacture, where the cost can be spread over large volumes of products.) This makes it necessary for each photographer to determine his own standards, for highest quality work. After selecting the sensitized materials, exposure meters, and cameras he intends to work with, test photographs should be made and evaluated and, perhaps, a new exposure index value for the meter setting determined. More often than not this will coincide with the value the manufacturer assigned to the film. However, in some instances a wide divergence in lens transmission, shutter performance, or meter interpretation may lead to a value that does not agree with the manufacturer, but which may be used with the particular combination to produce good pictures.

It might be worth while to consider that, when the safety factors have been disregarded, and with other special conditions, including shutter speeds, useful high exposure index values may be claimed. It should be obvious that this holds true for a single set of conditions, and is not representative of the standard value that may be assigned to a given product.

ON THE PHOTOGRAPHIC DYE REVERSAL

Simpei Tutihasi*, Mikio Tamura, and Y. Hayakawa†

ABSTRACT

Dye reversal on surface latent images and internal latent images has been studied. It is concluded that the dye reversal maximum in the blue spectral region is quite different in nature from the maximum in red spectral region.

THE PHENOMENON called "dye reversal" has been observed and reported by many authors.[1,2,3,4] The latent image made by a pre-exposure on a photographic film may be destroyed by a post-exposure to light of the proper wavelength in the presence of desensitizing dyes. The sensitivity range of the dye reversal is spread throughout the visible spectrum as well as in the red and infrared region. As reported by Mauz[2], Carroll and Kretchman[3] and by Cohen-Solal[4], generally two

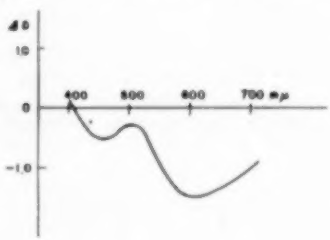


Fig. 1. Dye reversal sensitivity curve of bromide emulsion. The abscissa represents wave-length of the post - exposure. The ordinate represents the change of the density. Standard level of the density is taken at the density given by the pre-exposure.

maxima of reversal are observed in the dye reversal spectrogram, one of which is around 450 mμ and the other in the red region. It is also reported[5] that the reversal in the blue disappears when the second exposure is given in an oxygen free atmosphere. Carroll and Kretchman[3] showed that the strong reversal band in the blue agreed in wave length with the absorption band of the dyes adsorbed to the silver halide. On the other hand, concerning the strong reversal band in the red and infrared, neither the effect of oxygen nor the agreement in wave length with the absorption of the dyes is observed. From the facts observed so far, it is concluded that the dye reversal is a combination of two types of phenomena, one being due to a photo-oxidation process and the other merely an enhancement of the Herschel effect in the infrared. This conclusion is, however, not yet completely established. Some workers[4] believe that both the observed bands are actually caused by the Herschel effect. Hence it seems desirable to study the behavior of the surface latent image and that of the internal latent image separately in each case.

First of all, the effect of oxygen upon the dye reversal of the surface latent image was checked, using bromide emulsion. The emulsion used showed a dye-reversal sensitivity as plotted in Figure one against wave length, when dyed with phenosafranine, under normal conditions. Strips of test emulsion were first given homogeneous pre-exposure, that would give a density of 1.0 upon development, then treated with the dye solution and dried. The post-exposures in the blue (400 mμ–470 mμ) or the red ($\lambda > 650$ mμ) were then applied to the strips through an optical wedge, the strips being either in air at one atmosphere or in nitrogen at one-half atmosphere. The strips were then developed by the glycine surface developer[6] for five minutes at 20C. The dyes used were phenosafranine and pinakryptol green. The results are shown in Figure two for the case of phenosafranine. Pinakryptol green showed nearly the same results. The concentration of dye solution was 1:5,000 in the case of phenosafranine and 1:20,000 for pinakryptol green, 0.1% potassium bromide having been always added. Figure two simply confirms the results previously reported.[3,5]

The effect of desensitizing dyes on post-exposure in the spectral region of shorter wave length.

1. Surface latent image.

The experiments described below were all carried out in air, because dye reversal in the region of shorter wavelengths occurs only in the presence of oxygen and it is clear that the oxygen has nothing to do with the dye reversal by the red light post-exposure.

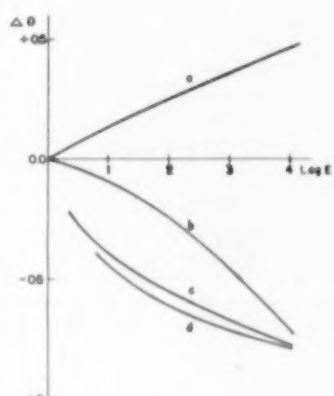


Fig. 2. Effect of oxygen on dye reversal. Curve a = blue post-exposure, film in nitrogen; Curve b = blue post-exposure, film in air; Curve c = red post-exposure, film in nitrogen; Curve d = red post-exposure, film in air. The abscissa represents the relative energy of the post-exposure. The scale for the blue exposure is not necessarily the same as for the red. The ordinate represents the variation of density. The standard level is taken at the level of density of the pre-exposure.

Cine positive film was used. Two maxima of dye reversal were observed when the film was dyed with phenosafranine, one around 450 mμ and another around

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700 m μ. Two strips of film were given the same even white light pre-exposure corresponding to a density of 1.5 and then one of the strips was dipped in a 1:5,000 water solution of phenosafranine containing 0.1% potassium bromide for ten minutes at 20C, the other in a 0.1% potassium bromide solution for ten minutes at 20 C and dried.

This procedure was done very carefully to keep the two strips in the same condition, except that one adsorbed dye molecules and the other did not. The procedure described above was always the same throughout the following experiments.

After the strips had dried, the post-exposure was given through an optical wedge using a filter passing light of 400 m μ to 470 m μ wave length. The time interval between the pre-exposure and the post-exposure was always 20 hours. A 300-watt tungsten lamp was used for the light source and the distance between the strip and the light source was two feet. Exposure time was fifteen minutes. Then, the two strips were developed at the same time by the "energetic surface developer" described by Stevens[6] for five minutes at 20° C. The results are shown in Figure three.

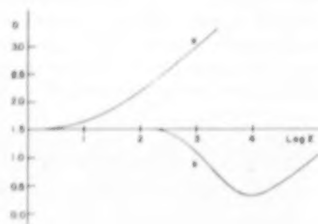

Fig. 3. Effect of blue post-exposure on the surface latent image. Curve a = without dye. Curve b = with dye. Phenosafranine was the desensitizer. The second sensitivity was observed after the reversal in curve b like in the case of the solarization.

From Figure three, it is clear that the density due to surface latent image is decreased by a post-exposure to blue light when the emulsion has adsorbed dye molecules. On the other hand, the density increases when no dye is adsorbed.

2. Internal latent image.

In the case of internal latent image, the blue light post-exposure was given for thirty minutes, keeping the other conditions the same as in the case of surface latent image. Internal development was also done by the procedure reported by Stevens[6] using the deep internal developer, after the surface latent image had been destroyed by a potassium ferricyanide bleaching bath for ten minutes at 20C. Results are shown in Figure four.

As shown in Figure four, the increase of density due to internal latent image was inhibited by the presence of the desensitizing dye, but no reversal occurred

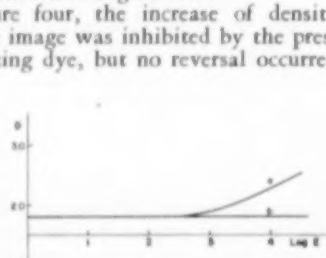

Fig. 4. Effect of post-exposure on the internal latent image. Curve a = without dye. Curve b = with dye. The density of the pre-exposure is 1.8 in this case. The internal latent image of the dyed emulsion does not increase the density at all.

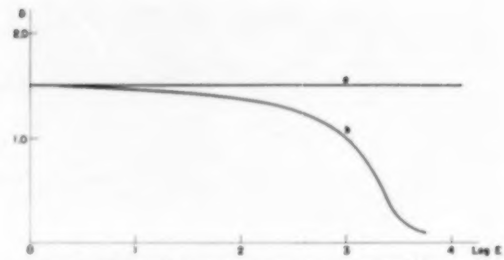

Fig. 5. Effect of the red post-exposure on the surface latent image. Curve a = without dye. Curve b = with dye.

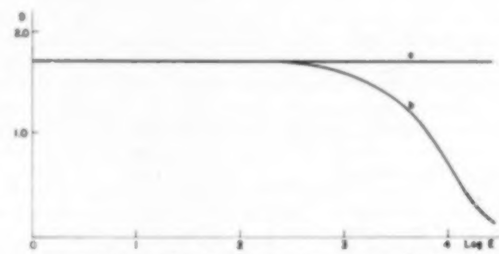

Fig. 6. Effect of red post-exposure on the internal latent image. Curve a = without dye. Curve b = with dye.

in spite of the fact that the post-exposure was given for twice as long as in the case of the surface latent image.

The effect of desensitizing dyes on reversal by longer wave length light.

The same experiments were done using a filter which passed light of wave length longer than 650 m μ, keeping the other conditions exactly the same as above. The post-exposure was given for fifteen minutes in the case of the surface latent image, thirty minutes for the internal latent image.

The results for both cases are given in Figure five and Figure six. Figure five shows the dye reversal of the surface latent image and Figure six that of the internal latent image. In both cases, it is clear that the desensitizing dye greatly increases reversal of the latent image by long wave light.

Conclusion.

From the above experiments, it is very clear that in dye reversal the blue post-exposure is only effective in destroying the surface latent image, provided oxygen is present. On the other hand, the red light post-exposure can destroy both surface and internal latent image, no matter whether oxygen is present or not. These facts strongly support the opinion of Carroll and Kretchman,[3] who concluded that the dye reversal in the short wave length region was due to a photo-oxidation, and that reversal in the long wave length region was merely an enhancement of the Herschel effect.

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THE DESIGN OF A SIMPLE PRECISION CAMERA

Alfred Simmon*

The quality of photographic lenses has undergone a rather spectacular improvement within the last fifteen years, and this is particularly true with respect to lenses made in the United States. This advance has been due to three principal causes: the introduction of new glasses, the invention of anti-reflex coatings, and the development of the high speed Computing Machine.

The design of cameras into which these lenses could be fitted has not always made similar advances, and consequently very often the final results are not nearly as good as the superior quality of the new lenses alone would make one expect. The design of a completely new camera became therefore desirable. Analyzing the requirements that such a new camera should have to meet is not a simple matter, as we shall see, but the results of such an analysis can be expressed in two words: *Precision* and *Simplicity*.

While the need for precision will hardly be questioned, the importance of simplicity is not always equally appreciated and is often obscured by the desire for spectacular but not always sound "sales features." It cannot be emphasized enough, however, that a "simple" camera takes better pictures, and has a smaller size, less weight, better reliability and last but not least, a lower price. (While we are not at this time primarily concerned with the economic aspects of camera design, we cannot completely lose sight of the fact that even the best camera is of little benefit to most people if it is so expensive that only few millionaires can afford it.)

The first part of this paper discusses briefly the conditions that determine the design of such a camera. This preliminary discussion can conveniently be divided into four groups concerned respectively with sensitized material, the rangefinder or its equivalent, the lens and shutter assembly, and the camera body. In the second part the camera itself as it was subsequently developed is described.

Choice of Film Format

Roll film, sheet film, or pack film? This choice depends essentially upon the answer to the question: "Which type of film can be positioned in the focal plane with better accuracy, flatness, and consistency?" Contrary to the views of some experts who favor sheet film, our own experience as well as experiments conducted by our Research Department, point to the superiority of roll film. In our opinion, roll film can be held in the focal plane more consistently with better accuracy and flatness.

Picture Size Considerations

The short focus lenses used on 35mm cameras have a resolving power superior to that of the lenses of longer focal length used on larger cameras, but unfortunately, not sufficiently superior to compensate for the inevitable loss of detail due to the higher magnification by which 35mm negatives must be enlarged. Therefore, larger negatives yield sharper enlargements.

Fig. 1. Size and shape of the Omega 120 camera which was designed with "human engineering" in mind to have proportions and functional characteristics suiting the human body.

The next larger negative size in common use is $2^1/_4'' \times 2^1/_4''$ which is made on #120 roll film. Unfortunately, it is not very practical because it is square, whereas the most common enlarging paper sizes are rectangular, the short side usually being $^4/_5$ as long as the long size ($8'' \times 10''$, $11'' \times 14''$, $14'' \times 17''$, $16'' \times 20''$). For

* Simmon Brothers, Inc., 30-28 Starr Avenue, Long Island City 1, New York. Received 14 May, 1954

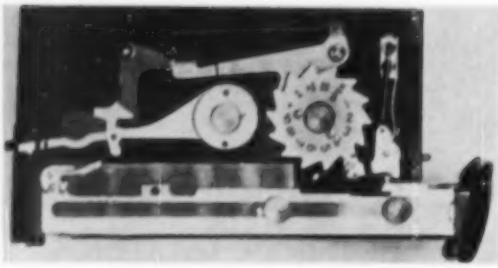

Fig. 2. Mechanism for automatic operation of the Omega 120 camera shown with the rear cover removed. A single motion sets the shutter, winds the film, advances the exposure counter.

example: by enlarging a $2^1/_4'' \times 2^1/_4''$ negative $4^1/_2$ times we obtain an image on the easel of $10'' \times 10''$, but actually print only $8'' \times 10''$, i.e., lose $1''$ on either side. This waste can be eliminated by using the same #120 roll film and simply adding $^1/_4''$ to the width of the negative on either side, i.e., making the negative $2^1/_4'' \times 2^3/_4''$. This size needs only a magnification of a little more than $3^1/_2$ times to produce an $8'' \times 10''$ print, without any waste at all. The reduced magnification is, of course, most welcome, since it automatically improves the sharpness of the print.

The advantages of this modified negative size may also be stated a little differently as follows: Enlarging a $2^1/_4'' \times 2^1/_4''$ negative $4^1/_2$ times produces an $8'' \times 10''$ print, but enlarging 2-$^1/_4'' \times 2^3/_4''$ negative 5 times yields an $11'' \times 14''$ print. In other words, increasing the magnification by only 10% almost doubles the size of the print.

A well-built camera of this negative size will produce negatives which can be enlarged to $16'' \times 20''$ without difficulties. It appears, therefore, unnecessary to consider still larger negative sizes since apparently little can be gained by it. The camera would be larger and less convenient to handle and the depth of focus of the longer focal length lens, which by necessity would have to be used, would be inferior to that of the lens of the smaller camera.

Film Flatness Considerations

This concerns one of the most neglected and least understood, but at the same time, most important features of any camera, because all the precision built into a camera is wasted unless the film is kept accurately flat and in the focal plane. Even expensive cameras have often only primitive and ineffective film flattening means, consisting usually of a sheet metal plate of questionable flatness which is constantly pressed against the back of the film by a weak spring. (A strong spring would interfere with film winding!) The position and flatness of the film becomes thereby sufficiently uncertain to cause a considerable percentage of all negatives to be of less than the best possible sharpness. A more perfect arrangement should have the following features:

1. The pressure plate must be really flat. Instead of sheet metal, a non-metallic, ceramic material, accurately ground and non-warping, was found to be most satisfactory.
2. Much stronger pressure than customary must be applied to the plate. This pressure must be relieved during film winding.
3. The pressure must be applied only immediately before and during an exposure so that temperature and humidity changes have no time to cause warpage of the film once it has been sandwiched between aperture and pressure plate, i.e., the mechanism must be actuated by the shutter release trigger immediately before each exposure.

Reflex or Rangefinder Focusing

In a reflex camera, a lens is focused until a sharp image appears on a ground glass. Most people, although usually not aware of this fact, are unable to focus consistently to the very best, critical sharpness. The human eye cannot readily detect small departures from the condition of utmost sharpness, and the lens position becomes thereby slightly uncertain, resulting in a considerable number of negatives that have less than the best possible sharpness.

In a rangefinder, two images of the same object, seen from two different points, are brought into register. Most people find it much easier to decide when, in a *good* rangefinder, the two images are in register, than to decide when a ground glass image is really sharp and not merely approximately sharp.

A camera equipped with a *good* rangefinder will, therefore, produce a higher percentage of really sharp pictures than a reflex camera.

Desirable Characteristics of a Rangefinder

A *good* Rangefinder must have the following features:

1. In order to be sufficiently sensitive, the Rangefinder must have a reasonably large base distance (the distance between the two points from which the object is seen). However, it is a mistake to make this distance too large, because then the two images may become so dissimilar that they can no longer be brought into register at all.
2. Additional sensitivity should be obtained by magnifying the images (in a telescope), rather than by an excessively large base distance. (This explains why it is unsound to combine rangefinder and viewfinder. The viewfinder shows the entire field, but necessarily at a reduced scale. The rangefinder should, for best accuracy, show the center of the field, at a magnified scale. No optical system can do both, and separate finders are, therefore, preferable).
3. Two superimposed images can be brought into register faster and more precisely than two halves of a split image.
4. The optical system must be so designed that the two light beams which form the two images, are of equal length. Otherwise, one image becomes slightly larger than the other, causing focusing errors, (so called "cross field error").
5. The images should be as bright as possible.
6. The field visible in the rangefinder should be reasonably large so that the object to be focused on can be found quickly and conveniently.

Focal Plane or Lens Shutter?

In a so-called focal plane shutter a curtain with a slot travels, during an exposure, immediately in front of the film across the length of the picture. Its chief advantage is that, by using a narrow slot, very short exposures (1/1000 sec.) can be obtained, but otherwise this shutter has very undesirable properties:

1. It is practically impossible to expose all parts of the picture with the same speed. The curtain usually gains some speed during an exposure and ingenious compensating methods are complicated and often ineffective.

2. It is difficult to combine a focal plane shutter with synchronized flash. While the exposure of any part of the negative may be very short, the total time required by the curtain to travel across the entire length of the picture becomes quite long (1/30 sec. or more). Special lamps with extended flash time (G.E. #6) are needed, but these lamps have a relatively low light output. It is still more difficult to use a stroboscobic flash in connection with a focal plane shutter. The only way in which this can be done is to use a very large slot which uncovers the entire negative at least for one instance during which the stroboscobic flash should take place. Obviously that can only be done in a substantially dark room and any combination of daylight and stroboscobic flash is not possible.

3. Moving objects are shown distorted (elliptical wheels of moving motor cars): In a lens shutter a number of thin blades, usually arranged concentrically between the glass elements, are withdrawn simultaneously during an exposure. At present, the highest speed usually does not exceed 1/400 sec. but the shutter is free from the difficulties described above.

The Focusing Mechanism

The focusing mechanism adjusts the distance between the lens and the film, usually in accordance with the indications of the rangefinder or with the appearance of the ground glass image of a reflex camera. For small cameras the helical mount has been most popular in the past, i.e., a mount which comprises essentially a hollow screw surrounding the lens, and which is rotated by the operator. These mounts are fairly easy to manufacture on automatic machinery and that seems to have been their prime attraction, but they force the hand of the operator to assume a very inconvenient, cramped position which is not very helpful in holding the camera steady. From the standpoint of "human engineering" an arrangement is preferable which terminates in a rotating wheel or knob which has a horizontal axis at right angles to the optical axis of the lens, preferably disposed at the right side of the camera because most people happen to be right-handed. A device of this type is a little more difficult to manufacture since it includes a precision-made slide as well as a rack and pinion which also has to be made with great precision. A mechanism of this type, however, can be operated much more conveniently and with greater certainty.

A word remains to be said about the sensitivity of the focusing mechanism. If it is too coarse, i.e., if its motion is too rapid, it is difficult to position it with accuracy; if it is too slow, the rangefinder image or the ground glass image of a reflex camera will change so imperceptibly that the operator has difficulties finding the best point. Experience has shown that the most practical ratio provides a little less than one revolution of the focusing knob when the distance is changed from 3 feet to infinity.

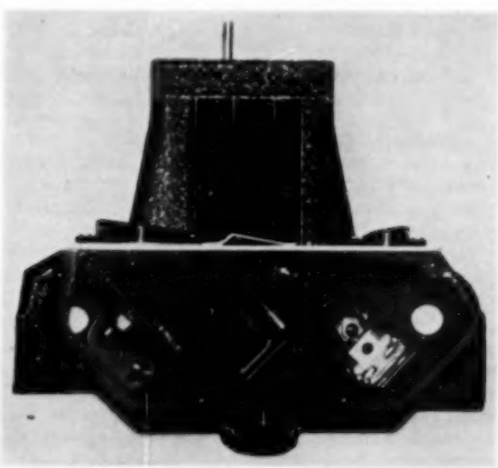

Fig. 3. View of the range finder mechanism in the Omega 120 camera.

f/Number and Design of Camera Lens

The f/number merely states that the diameter of a lens is a certain fraction of its focal length (for example: f/2 means that the diameter of a lens is $^1/_2$ of its focal length). It should, therefore, be obvious that the f/-number is nothing but a rather crude measure of the light gathering power of a lens (unreliable because it makes no allowance for light losses within the lens) and that there is no relation at all between image quality (sharpness and color correction) and f/number. Contrary to a popular impression of long standing, a low f/-number, for example: f/2, does not mean an exceptionally well corrected lens, but merely a big lens. The high esteem in which these lenses are still held by some people is a remnant of the days of fifty years ago when the chief trouble of photographers was underexposure.

These conditions ceased to exist when more sensitive films and better artificial light sources became available and today resolving power, color correction and generally, freedom from aberrations are infinitely more important than a low f/number.

Freedom from aberrations can be built into a lens with a moderately high f/number more easily and more perfectly than into one with a very low f/number. (The aberrations of a high f/number lens are smaller than those of a stopped down low f/number lens, i.e., a f/3.5 lens is better than an f/2 lens that has been stopped down to f/3.5). For all around use an f/3.5 lens appears to be a suitable choice, combining adequate light admittance with relatively high freedom from aberrations.

The best available design of such a lens seems to be a triplet of which the rear element consists of two ce-

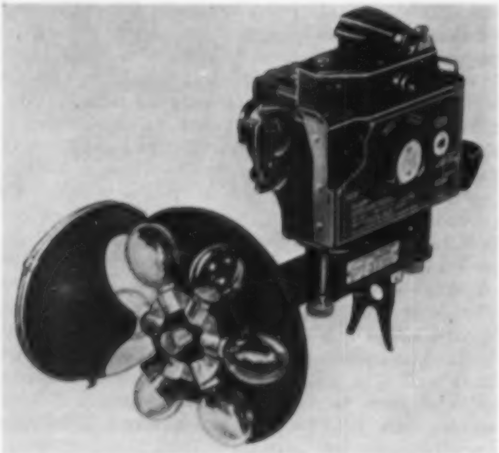

Fig. 4. One of the accessories developed for the Omega 120 camera is this flash attachment with rotatable lamp turret linked by gears with the film advance mechanism.

mented components so that the lens really is a four-element lens. This type of lens which is usually called the "Tessar" type has been considerably improved by making at least one of the elements from one of the new high index glasses.

Exchangeable Lenses

There is no question that the possibility of using a number of exchangeable lenses would add to the versatility of any camera. Unfortunately it also adds greatly to its complexity, and as a matter of fact a really satisfactory solution of this problem has yet to be found. The obstacles that would have to be overcome are formidable. They may briefly be described as follows:

1. Focusing Mechanism. The sensitivity of the focusing mechanism should be matched to the focal length of the lens, i.e., it is impractical to use the same mechanism for lenses of different focal lengths, but each lens should have its own mechanism. This in turn has lead to the almost universal use of helical mounts for this purpose. The disadvantages of this type of mount were described in a previous paragraph.

2. Shutter. The large majority of all cameras with exchangeable lenses are equipped with focal plane shutters. This renders the shutter entirely independent of the lens, but in view of the many objectionable properties of the focal plane shutter, this appears to be a very high price to pay. A few cameras have used lens shutters which were mounted behind the lens instead of between the front and rear elements. The disadvantage of this arrangement is that the shutter has to intercept a divergent beam and then, consequently, its aperture becomes about twice as large. Even for 35mm cameras this is very undesirable. For larger sizes the shutter dimensions would be clearly impractical.

3. Rangefinder. The sensitivity of a rangefinder should be matched to the depth of focus of the lens, i.e., to its focal length. This is generally disregarded and the same rangefinder is coupled to lenses of widely varying focal lengths. The result is that the rangefinder becomes annoyingly over-sensitive for the wide angle lens and entirely too unsensitive for telephoto lenses.

4. Viewfinder. Here again complications arise. In order to match the field of the viewfinder with the image produced by different lenses, one must either use a viewfinder with adjustable magnification which is complex, or a turret containing several viewfinders which is worse, or a set of masks which have the disadvantage that for a telephoto lens the visible image becomes exceedingly small.

The difficulties confronting the designer of a rangefinder and viewfinder system for a camera equipped with exchangeable lenses are so formidable that some designers have abandoned the entire system and have gone back to the rather ancient single lens reflex camera. Again a high price must be paid for this expedient because one has to focus on a ground glass with all the uncertainties described in a previous paragraph. Even then a wide angle lens can generally not be used, since the mirror interferes.

In the interest of simplicity it was therefore felt that it would be better to equip the camera with one lens only and abandon the feature of lens interchangeability, particularly since statistics have shown that only a relatively small percentage of photographers actually use more than one lens even if they possess a camera which has this feature.

Folding Camera or Rigid Body?

Folding cameras were invented a century ago because this design was a necessity for the 8" × 10" cameras then in common use, but today their use for small negative sizes cannot be justified. Any folding camera is necessarily more complicated and less rigid than a camera with a one-piece body. The various camera elements can be mounted on a simple rigid body with greater accuracy and their precision alignment maintained for a longer time than on a much more complex folding structure. For best results, a rigid body, preferably formed by a casting (not by sheet metal) should be used.

Manual, Interlocked, or Automatic Operation?

In a manually operated camera the roll film is wound until a number, printed on the backing paper, appears in the customary red window, and the shutter is set independently. In a camera with interlocked operation the shutter cannot be set unless the film has been wound, or vice versa. In an automatic camera a single motion by the operator simultaneously sets the shutter and winds the film. Interlock prevents double exposures, but does not speed up the operation of the camera. Automatic operation does both.

While picture quality is not directly affected by the method of operation, the opportunity to take certain pictures (action shots) may be lost unless the camera can be readied quickly. Fully automatic operation is, therefore, desirable.

The film winding and shutter setting mechanism may be actuated either by a rotating wheel or crank, or by a

reciprocating handle. With a lens shutter, the reciprocating design becomes faster, simpler and requires fewer parts.

The Shape of the Camera Housing

"Human Engineering" is a term which was adopted during the war and which was applied to research relating the size, shape and other properties of machinery to the proportions and functional characteristics of the human body. (For example: aircraft controls).

A camera is a picture taking machine which is to be operated by a human being involving mainly the use of hands and eyes. By applying the lessons which were learned during the war, it is possible to give a camera a shape which fits the human hands more easily and conveniently than older models. Controls can be arranged in proper relation to the two hands of the operator. (Reference has already been made to certain aspects of this problem in the paragraph on focusing movements.)

These considerations result in an unconventional shape and appearance which, however, drastically improve the results since the camera can now be handled with surprising ease and convenience. In this particular respect it contrasts very favorably with certain older models which were quite perfect mechanically and optically, but which had such an unfortunate shape that unnecessary stress was imposed upon the operator and consequent results were not nearly as good as they otherwise could have been.

It can be seen that the decisions that had to be made even before a design could be started were not simple and required experience, sound judgment and engineering skill of a high order.

A camera developed accordingly is shown in Figure one. Its most conspicuous feature is its unconventional shape. During operation the camera is held by both hands. The left hand engages a plastic handle molded to fit the shape of the human hand. The trigger release is placed somewhat in front of this handle within convenient reach of the index finger of the left hand. The release mechanism was purposely designed with a relatively long stroke ($^{3}/_{4}''$) whereby effortless operation could be obtained. The first half of the stroke is utilized to actuate the pressure plate which is normally retracted and brought forward immediately before an exposure thereby sandwiching the film firmly between pressure plate and aperture plate. The back carries a depression of its upper left-hand corner providing a convenient rest for the left thumb. The unusually large ($1^{1}/_{2}''$) focusing wheel is placed on the right side of the camera and is operated by the thumb and index finger of the right hand, while the rounded handle of the film transport mechanism rests in the palm of the right hand. The camera can be held firmly and conveniently in this manner, particularly when during the exposure it is slightly pressed against the forehead of the operator. The rangefinder and viewfinder windows are in the middle of the camera so that they can be used with either eye. They are close enough to each other to permit fast and convenient switching of the operator's eye from one to the other. Much of the mechanism for the automatic operation of the camera is mounted within the rear cover which is a departure from the current practice, but is very practical. Here a large area is available, and by increasing the thickness of the camera by less than $^{1}/_{4}''$, the entire mechanism could be very conveniently housed. This mechanism is shown in Figure two with the cover removed, and it can be seen that it has relatively few parts in spite of the fact that it performs some rather complex functions. It counts the exposures, it locks the rear cover so that it can be opened by the operator only when the film is completely wound, either on its original spool or on the receiving spool, (i.e., the camera cannot be opened by mistake in the middle of the film), it shuts the observation window by means of which the first frame is positioned and it adjusts the stroke of the reciprocating handle to compensate for the fact that the diameter of the film spool increases while film is wound on it. A view of the open rangefinder is shown in Figure three. The viewfinder is mounted on top of the rangefinder and is connected to a small cam on the focusing mechanism which causes it to tilt slightly for automatic parallax compensation at close distances.

The lens is a four-element 90mm f/3.5 Omicron lens developed by the Wollensak Optical Company specifically for this purpose. One element is made from high index glass. This is a very remarkable lens with unusually high resolving power. The shutter is a Wollensak Rapax with speeds from 1 to $^{1}/_{400}$ of a second which was modified slightly so that it could act in cooperation with the automatic shutter setting and with the release mechanism of this camera.

The camera and Rangefinder bodies are made from magnesium die-castings. Nonfunctional parts such as rangefinder covers and others are made from plastic, either molded nylon or high impact phenolic resin. Stainless steel is used liberally for moving parts of the mechanism. The camera is relatively small considering its negative size, $5^{1}/_{2}''$ wide, approximately $4\text{-}^{1}/_{4}''$ high, (not counting the viewfinder) and about 5" long. The weight is correspondingly small, approximately 2 lbs, 9 oz.

A number of accessories were developed for this camera, the most noteworthy of which is a flash attachment which includes a rotatable lamp turret which accepts six flash bulbs. A gear arrangement links this turret to the film advance mechanism so that a new lamp is placed in operating position automatically as soon as the operator advances the film. See Figure four.

Prototypes of this camera were first available in 1950 and extensive tests have since been made. A number of the cameras have been made available to the Armed Forces.

Experiences were very favorable and only a relatively small number of minor "bugs" had to be ironed out. Performance chracteristics, particularly resolution of the negatives was very good, and at least equal, but in most instances definitely superior to those obtained with existing, generally imported equipment.

Lack of space does not permit describing even briefly the very interesting machine tools that had to be developed to permit the production of this camera under the wage and salary conditions prevailing in this country at a price competitive with those of imported cameras.

AN IMPROVED SYSTEM OF UNITS FOR THE CALIBRATION OF PHOTOGRAPHIC ENLARGERS AND RELATED EQUIPMENT

J. H. Troup, Jr.*

Recall for a moment the variables affecting exposure which the photographer must adjust or take into consideration in the making of prints by enlargement. He has to deal with relative aperture, seconds of exposure time, minutes of development time, and magnification in diameters. He also may take into consideration, if he is more scientifically minded, negative density, the emulsion speed of his paper, and perhaps even other variables, for there are many other factors that influence exposure to at least a minor degree. At present the units used to indicate these exposure variables bear no simple relationship to each other and, furthermore, none of the units is significant or meaningful to the printing process.

It has long been recognized that the work of the enlarger operator could be simplified if some order were brought into this chaotic array of exposure variables. Toward this end, attempts have been made to correlate these variables by means of charts and calculating devices. A typical chart found convenient by some printers is one relating exposure time to magnification. This type of chart allows the printer to make enlargements from the same negative at different magnification without making test strips to determine the exposure, except for the first print. A typical computing device that is an improvement on this system includes more variables. It relates negative density, exposure time, magnification in diameters, and sometimes relative aperature and emulsion speed. These devices are generally of the circular slide rule type.

Devices like these have been aids, but even the best of them have failed to accomplish all that might be desired. Their advantages have been limited and they have found little popularity in practical photography.

Mathematical Relations of Exposure Variables

This paper attempts to describe a superior system for correlating the array of exposure variables described above. The basic plan is:

1. To calibrate all variables with the same units so that variations within one variable may be understood in relationship to variations in any other.
2. To give this uniform system of units a direct and significant relationship to the exposure product, so that a given change in any variable will produce a known change in exposure.
3. To make the relationship between these units of exposure to the exposure product itself a logarithmic one. Thus, the mathematical considerations in exposure problems would be simplified by being changed from products to sums, and any given change in exposure, as measured in these units, would always have the same visual significance in the print.

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It must be made clear how the above 3 points can be satisfied in practice. To do this it is necessary to begin with the familiar equation:

$$E = it \tag{1}$$

where E is exposure, i is intensity, and t is time. In properly exposing photographic paper with an enlarger, however, these terms take on more limited definitions. E will be defined as the quantity of exposure necessary to produce a given density on a specific emulsion under specific processing conditions. E is therefore a constant for our present purposes. In the equation, i is the intensity of light at the emulsion surface, and t is the duration of the paper's exposure to light. However, if the equation is to accurately express the conditions involved in making enlargements, it must be expanded to include the most important exposure variables. The negative density, lens aperture, and the magnification must be included because these three variables influence the value of i in equation (1). This is not a simple job because the present numerical systems used to indicate these variables could not by their very natures be substituted in equation (1) without making it too complex to be of value. Therefore, as suggested above, it is necessary to translate each of these variables into a new system of measurement the values of which will vary directly with i. Expressing this mathematically:

$$i = kpam \tag{2}$$

where k is a constant, p is the negative density as translated into the new system, a is the aperture as translated into the new system, and m is the magnification as translated into the new system. That equation (2) is a practical possibility, and that the interrelation of such variables as aperture and magnification does not render it otherwise, is a fact which can be proved. However, the proof will not be presented here as it would needlessly lengthen the text.

The Log Exposure System

By substitution of equation (2) in equation (1):

$$E = kpamt \tag{3}$$

Taking the log of both sides, and dropping the resulting log k as unnecessary in an equation not meant for dealing with the absolute values of log E, then

$$\log E = \log p + \log a + \log m + \log t \tag{4}$$

To give full status and meaning to equation (4), it remains to be shown that although equation (4) was built by considering only one density in the print being produced by one density in the negative, this fact does not prevent use of the equation in everyday photography involving negatives and prints of differing densities.

To demonstrate this fact is not difficult, for, if it is true that the above mathematical relationship exists between the variables mentioned when considering only one density in the negative producing a predetermined correct density in the print, then all other negative densities and their corresponding print densities will, so to speak, fall in line and maintain their proper relationships to the primary densities. Equation (4), therefore, also shows the relationship which exists between the variables when making properly exposed prints from real negatives. Of course, log E and especially log p under this interpretation take on slightly more useful and more comprehensive meanings. Log p represents what might be understood by the term "negative printing speed," and this term will be used later when referring to log p. Negatives with high printing speeds print faster than negatives with low printing speeds when all other variables are equal. Log E now indicates the sum of the quantities log p, log a, log m, and log t (printing speed, aperture, magnification, and time; each expressed in the new system) necessary to produce a properly exposed print on a specific emulsion under certain specific processing conditions.

In the relationship expressed by equation 4, and in the new system for expressing negative density, aperture, magnification, and time (for time is now log time) are all of the advantages sought after and listed in the three points above. To reap the advantages of this new system, it is only necessary that enlarging equipment be calibrated in this system so that readings can be directly substituted in equation (4).

Experience has shown it to be practical to construct log scales (base 10) on which the smallest divisions are 0.05 and every other tenth division (like 0.2, 0.4, 0.6, etc.) is identified by numbers. For convenience, when using this system, we will call each 0.1 variation in exposure one exposure unit.

But what are the advantages? In what ways will these new calibrations simplify the process of enlarging? The answers to these and other questions will become apparent in the discussion of advantages which follows.

Developing an Exposure-Density Relationship

First, as mentioned above, a system has been created in which a given change in exposure (log E) when measured by these units, will always produce the same visual difference in the print. This fact is true regardless of the time of exposure, the aperture, the magnification, or the printing speed of the negative. This means that a relationship is established between exposure change and the resulting density change which the operator can anticipate. An improperly exposed print is automatically evaluated in terms of the number of exposure units of error. The operator therefore can correct for exposure errors more accurately and more rapidly than was formerly possible when no simple relationship existed. The exposure correction could be made by resetting the timer or aperture control or both.

Consider some methods that will help an enlarger operator to build in his mind the vivid mental image of the exposure-density relationship, which can so easily be developed in conjunction with this system. First, the operator might expose a series of prints at varying exposures making each print different from the preceding one by one exposure unit and arranging to have the middle print in the series nearly correct in exposure. These prints then become samples of the exposure-density relationship. They can be kept handy until they are thoroughly "set" in the operator's mind. For another method the operator might use a grey scale, exposed with a one exposure unit difference between steps, to familiarize himself with the relationship. Another help would be for the operator to familiarize himself with the log exposure range of his paper. By simply multiplying the log exposure range by 10, he will have the total exposure range from black to white in exposure units. If the exposure range of his paper is 12 exposure units, it will help him to visualize the important relationship about which we are speaking, to realize that this means that the addition of 12 exposure units will darken any white in which there is some detail to black with just noticeable detail, and that 6 exposure units will do approximately one-half as much, and so on.

The second advantage of this new system is closely related to the first. It is the very great ease with which printing-in and dodging can be carried out. This ease is apparent when you realize that each printing-in or dodging operation is simply a matter of exposure correction. In other words the operator can simply look at a test print and determine rapidly the number of exposure units to add or subtract in order to achieve a desired local effect.

Negative Printing Speed Determination

The third advantage is the great accuracy and speed with which first exposures of previously unprinted negatives can be made. This accuracy is achieved because the enlarger operator now has to evaluate only one variable, the negative printing speed. Log E being an ascertainable constant, the relationship in equation (4) means that the three variables of magnification, aperture, and time need not be considered independently of one another as is necessary when using ordinary enlarging equipment. With ordinary equipment the difficulty of trying to anticipate the exposure effect of several variables all acting at one time is the very reason for inaccuracy in judgment. In this system, the negative printing speed (which is directly related to density and can be evaluated just as easily) determines the sum of the three variables of magnification, aperture, and time even more simply and directly than the density of a negative determines its printing time in seconds when contact printing. This sum of course can be divided between the settings of aperture, magnification, and time as convenience dictates.

As a fourth advantage, consider the convenience of this system when making prints at several magnifications from the same negative. After the first correct exposure is made, the settings at subsequent magnifications can be immediately determined by simply maintaining the balance of equation (4); i.e., by making adjustments in other variables to exactly compensate for the change in magnification.

As a fifth advantage, consider how this new system facilitates the operation of flashing. Print flashing is frequently done by using the enlarger with the negative

removed as the light source. The big problem is the necessity for making test strips. This is necessary only because the variables of magnification, aperture, and time have never before been adequately related. With this system of calibration a certain total of light units set on these three variables will always produce the same exposure when flashing. The operator will come to know these flashing exposures and, therefore, the need for test strips will be eliminated. He will be able to produce flashing exposures of his choosing at will.

Additional Advantages of the Method

Additional advantages will occur to the reader. Each type of photographic worker will discover advantages in his own field. To conclude this list here are a few more.

One of these advantages is the convenience of being able to rate all previously printed negatives according to their printing speeds. The rating would allow reprinting a negative at any time without any testing. The ratings would also serve as a constant indication of the effect of development and exposure on the negatives. Printing speeds which produce best quality prints could be determined and used as a standard by which to judge negative production.

In making large prints which involve several or many separate exposures from one or more negatives much time and material can be saved by working out the perfect print in a small size on the emulsion intended for the large print. Then by using this system the large print can be made immediately and without further testing simply by keeping the total of aperture, magnification, and time the same as when making the small print.

When working with several paper emulsions of different speeds, there is another advantage of the new system. It is possible to change from one emulsion to the next, making the exposure compensations more accurately and more rapidly than before. This is possible whenever the sum log E has been determined for the other emulsion. Of course, conditions vary and even emulsions of the same name vary in exposure required, but log E is still fairly constant for a given paper and a given set of processing conditions, and when evaluated under conditions of actual use, it is more accurate than any other emulsion speed indicator possible.

Log E should be re-evaluated frequently for accurate work. This evaluation is especially important at the beginning of a day's work or when opening a new box of paper. The process of evaluation is simple. A standard test negative of known printing speed is used and, the resulting print is compared to a standard print. Then, by use of equation (4), log E can easily be found. Surprising as it may seem, no additional time is required to perform this operation. The test exposure is made while developing one print and is developed along with the next print to be developed.

Print Timer Calibration

To proceed further with the development of the system, it is necessary to investigate an extension of the general principle of calibrating the variable factors of exposure in terms of log exposure units. One of the variable factors, not included in equation (4), (because it is not usually known at the time of exposure) is the developing time. One way to include *this* factor in the system is to use an elapsed-time indicator (Figure one) the pointer of which returns to its starting position at the beginning of each timing interval, for timing print development and to calibrate this timer in such a way that it will indicate the effect of development in exposure units upon the exposed print. This timer, once calibrated, would not have its zero (0) at the beginning of its scale but at the position which the pointer occupies after the normal developing time has elapsed. At the position occupied by the pointer when a print has been overdeveloped sufficiently to compensate for 1 exposure unit under exposure is the −0.1 mark indicating that a print which develops to perfect density in this time was given 1 exposure unit less than that required for normal development. Other divisions on the clock dial are determined by the same general method. Obviously one timer scale will not suffice for all paper-temperature-developer combinations. Several interchangeable scales are a necessity. The new type of print timer, calibrated in log exposure units, will work hand in hand with the apparatus already described and extend the usefulness of the system. It can be used to relate to the equation exposures required at nonstandard developing times. For instance, if the first trial print comes to proper density in less than the normal developing time, say at plus 0.1 by the print developer timer, we then know that the exposure necessary to develop the print at the proper time would be the exposure previously given to this trial print minus 1 exposure unit. This type of timer can also be used to shorten or lengthen the developing time above or below normal for the purpose of controlling contrast or tone or for whatever reason may appeal to the worker. This new timer also aids the worker in two other ways. First, the scale for each

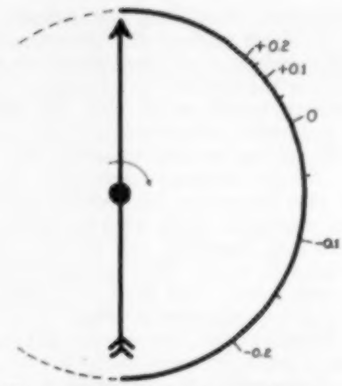


Fig. 1 Print development timer scale. The pointer is shown in the starting position. It reaches the zero position by the end of the development time specified for a particular brand of paper. If it is necessary to overdevelop a print until the pointer reaches −0.1 in order to reach perfect density, the indication is that the print was underexposed by one exposure unit (−0.1).

emulsion gives exact information regarding the exposure latitude of that emulsion in log exposure units. Second, because the worker soon becomes familar with the exposure-density relationship as described above he can more accurately visualize the effect of development in terms of density and exposure. Thus, in the very early stages of development he can ask himself if the number of exposure units of density change required to produce a good print are available to him by prolonging development. The answer to this question can often save several minutes of wasted time.

Compensating for Reciprocity Law Failure

In conclusion, there are two objections which might be raised against the adoption and use of this system. The first objection in order of importance might be that this system is based on the reciprocity law and therefore suffers as a result of the failure of that law. This is a natural objection, but it can be completely overcome by building a correction for reciprocity failure into the logarithmic time scale. Such a corrected scale would have the effect of compensating for reciprocity failure by giving slightly greater than indicated exposures for exposures made at low light intensities.

The second objection will probably rise out of the misunderstandings about the value and use of photoelectric exposure determining devices. Many workers are certain to wonder if the exposure determining devices now available will bring with them most of the advantages of this log exposure system. The answer is no, because these exposure determining devices can only assure that, within the accuracy of the instrument, they will aid the worker in reproducing a chosen part of the negative as a predetermined density on the print. To be sure this is a big help in fast production type work, but in high quality work or any other work in which the exact print density desired for any part of the negative can not be determined until after careful scrutiny of a test print, this is of little help. The problem in careful photography is a subjective one. A mechanical instrument can never be built to determine in which key a negative should be reproduced to be most aesthetically satisfying, to best convey an idea, or to best portray a texture, but the system described will be a very great aid in these problems because it will sharpen the operator's perception and judgment. The criticism concerning exposure devices does not mean that there is no place for them except in mass produced low quality printing. The log exposure system and the photoelectric exposure determining device can work side by side, each helping the other. The point made here is that each fills a need separate from the other.

The calibrating control on any electronic exposure device intended for use with this system should have its scale changed to a log exposure scale similar to those described above. This will speed calibration of the instrument and will relate it to the log exposure system.

As a final note, it might also be mentioned that consideration could be given to the adoption of the log exposure system to the calibration of cameras, or to the standardization of enlargers in terms of exposure units of intensity. The possibility of using electrical means for the solution of equation (4) is also an interesting speculation which should not be overlooked as a future development.

PROPOSED AMERICAN STANDARD PUBLISHED FOR TRIAL AND CRITICISM

H. R. Couch

All of the popular sizes of roll film except No. 828 are included in American Standard Dimensions for Amateur Roll Film, Backing Paper, and Film Spools, Z38.1.7–1950. When the original standard for roll film dimensions was developed prior to 1943, there was some discussion about incorporating the No. 828 size but it was agreed to omit it because at that time only one manufacturer supplied the film and the spool was a very special design.

When the standard came up for review in 1946, the question of including the No. 828 size was again raised because cameras were being produced for this film size by several manufacturers and at least one additional film manufacturer was contemplating the production of the film. However, no proposal for the No. 828 size was officially submitted to the committee for consideration.

Development of an American Standard for the dimensions of No. 828 roll film was started in 1952 by Subcommittee PH 1-1 on Dimensions of Films and Plates of ASA Sectional Committee PH 1 on Physical and Chemical Characteristics of Films, Plates and Papers. Mr. John G. Mulder of the Eastman Kodak Company is Chairman of Subcommittee PH 1-1. This committee agreed on the present proposal at its meeting in Rochester, New York, on May 11, 1954. Publication for trial and criticism during a three-month period was authorized by the Sectional Committee at its meeting on May 12, 1954. It is planned to include the substance of Proposed American Standard PH 1.21a in the next revision of Z38.1.7–1950, which will be numbered PH 1.21.

The proposed spool drawing is intended to establish the limiting dimensions for spools either with straight flanges or the type with flexible or spring flanges. It is intended to cover the space the spool will occupy in the camera cavity. Details of the design have been intentionally omitted in keeping with usual practices in drawing up national standards.

Comments and suggestions relating to PH1.21a will be welcome. They should be sent to the American Standards Association, Incorporated, 70 East Forty-fifth Street, New York 17, N. Y. before December 31, 1954.

Proposed American Standard

Dimensions for Amateur Roll Film, Spool, and Backing Paper No. 828

(Supplement to American Standard Z38.1.7—1950)

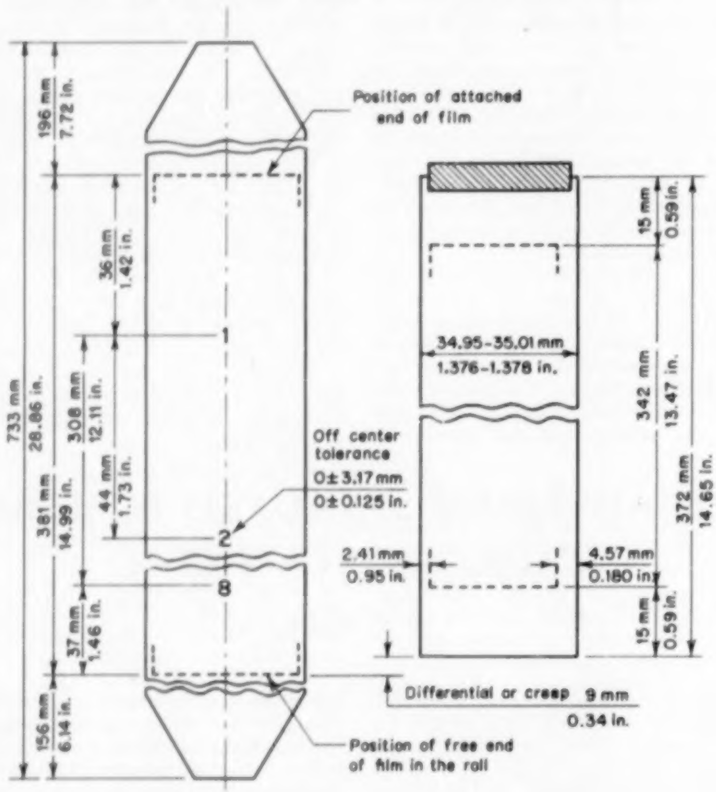
ASA
Reg. U. S. Pat. Off.

PH 1.21a

First Draft
August 1954

These dimensions apply to film spooled for non-automatic cameras

Used in cameras with nominal picture size: 28 × 40 mm



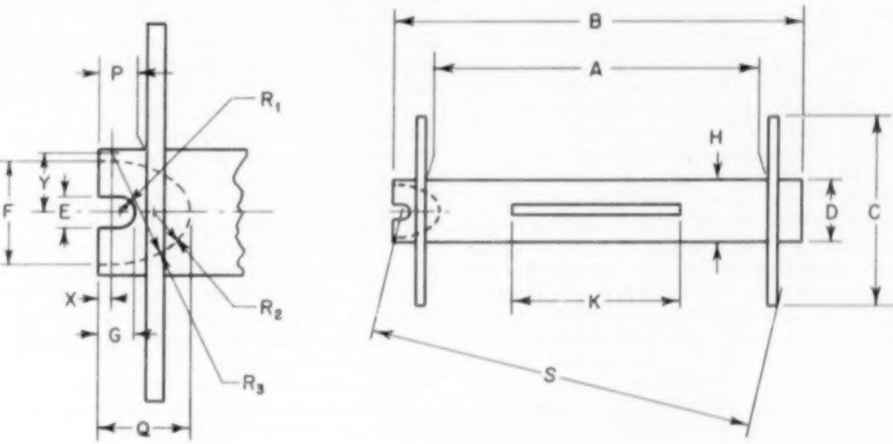
All dimensions are minimum except where tolerances are shown

Maximum film length shall be not more than 64 mm (2 ½ in.) over minimum

Proposed American Standard

Dimensions for Amateur Roll Film Spools No. 828

Used in cameras with nominal picture size: 28 × 40 mm



These dimensions apply to spools with resilient beaded flanges or parallel flanges.

Description		In.	Mm
A*	Max	1.410	35.81
	Min	1.395	35.43
B	Max	1.670	42.42
	Min	1.650	41.91
C	Max	0.760	19.30
	Min	0.740	18.80
D	Max	0.253	6.43
	Min	0.247	6.27
E	Min	0.060	1.52
F	Min	0.200	5.08
S	Max	1.554	39.47

Description		In.	Mm
G	Min	0.070	1.78
H	Max	0.253	6.43
	Min	0.247	6.27
K	Min	0.690	17.53
N	†	0.015	0.38
P‡	Max	0.122	3.10
	Min	0.084	2.13
Q	Min	0.189	4.80
R_1	Min	0.030	0.76
R_2	Min	0.075	1.91
R_3	Min	0.225	5.72
X	Min	0.026	0.66
Y	Min	0.125	3.18

* *"A" is the distance between flanges at core and must be centered with "B" ±0.006 in. (0.015 Mm).*
† *"N" equals concentricity of "C" & "F" and "C" & "D" or 1/2 total dial runout.*

Notes

1. *A minimum recess of F, Q, R_2 & R_3 dimensions is required at the key slot end of the spool to provide clearance for the winding key in the camera*
2. A key slot is required at one end of the core for use as a take-up spool in the camera. Key slots may be provided in both ends at the option of the manufacturer. Crossed key slots may also be provided in one or both ends.

‡ "P" represents the length of hub extension measured from its intersection with the flange.

AN AMERICAN STANDARD FOR COLOR DENSITOMETRY

J. P. Weiss*

THE FIRST step toward establishing standard techniques in the complex field of sensitometry of color films has been accomplished with the publication of *American Standard Spectral Diffuse Densities of Three-Component Subtractive Color Films, PH2.1-1952*. The purpose of this standard is to supplement the American Standard for Diffuse Transmission Density, Z 38.2.5-1946 by defining conditions suitable for certain basic density measurements of three-color monopack films. Both are available from the American Standards Association, Incorporated, 70 East Forty-fifth Street, New York 17, N. Y.

For the first ten years of its existence, the ASA sectional committee on Standardization in the Field of Photography, Z 38, confined its considerations of sensitometry to black and white films and printing papers. In 1948, Subcommittee 2 on Sensitometry undertook its first project involving color photography—a standard for color densitometers. The need for such a standard became acutely apparent when a manufacturer announced his plans to build the first commercial electronic color densitometer. Because there is considerable freedom in the choice of red, green and blue filters and since the readings are strongly dependent on the transmissions of the filters, it was obvious that formal agreement on this feature was needed to assure uniformity and agreement among densitometers of different manufacture.

A task group including representatives from Ansco, Department of Air Force, E. I. du Pont de Nemours, Eastman Kodak, National Bureau of Standards, Thaxton-Simonds Laboratories and Westinghouse tackled the problem. Their work was completed and the proposed American Standard submitted for approval at about the time ASA Committee Z 38 was disbanded and four new committees appointed to take its place. Thus PH2.1-1952 had the distinction of being the first American Standard approved by the new ASA Committee on Photographic Sensitometry, PH2.

Specification for color densitometers represents only one phase of the sensitometry of color films. Other problems in this field are being worked on by the Color Sensitometry Subcommittee of PH2, and additional standards will be issued as they can be completed.

General Problems of Color Densitometry†

Transmission density is defined as the common logarithm of the ratio of the radiant flux incident on the sample to the radiant flux transmitted.

$$D = \log_{10} \frac{P_0}{P_t}$$

It is evident that for any sample the density will have a strong dependence on the manner in which the radiant flux is measured. The measurement has both *geometric* and *spectral* aspects. The geometric aspect has to do with whether the incident light is diffuse or collimated, and the solid angle of the transmitted light which is collected and evaluated. The spectral aspect concerns the spectral energy composition of the incident light, and the spectral response of the receiver, which may be either a phototube, the human eye, or another piece of film. The silver deposits in most black and white films being relatively nonselective, the spectral aspect generally has only a secondary effect. When measuring the density of the highly colored deposits in a subtractive color film, however, the spectral considerations take on prime importance. Slight variations in the color quality of the incident light, for example, may cause great changes in the density readings.

One of the major complications of color densitometry is the fact that considerable option exists in the spectral conditions under which density may be measured. Each condition yields useful though different information; the choice of condition depends on the information desired. The two major classes of density are *integral* and *analytical*. Integral density is measurement of the color film *as a whole*. Analytical density refers to the characteristics of each component absorber of the film. It cannot be measured directly, but can be computed from integral densities.

Integral density‡, D_i, is defined as the density measured with radiant energy extending over a finite wavelength region. Mathematically,

$$D_i = \log_{10} \frac{\int_0^\infty J(\lambda)\cdot e(\lambda)\cdot S(\lambda)\cdot d\lambda}{\int_0^\infty J(\lambda)\cdot e(\lambda)\cdot S(\lambda)\cdot T(\lambda)\cdot d\lambda}$$

where

$J(\lambda)$ = the spectral energy distribution of the light source of the densitometer.

$e(\lambda)$ = the efficiency of the radiant energy transfer from source to receiver (i.e., modification by filters and other optical elements having selective absorption).

$S(\lambda)$ = the spectral sensitivity of the radiant energy receiver.

$T(\lambda)$ = the transmittance corresponding to the spectral density of the color film image taken *as a whole*.

If density is measured at a single wavelength, λ, *spectral density* is the result. Spectral densities have two important features which make them particularly useful: (1) Conditions for measurement can be rigorously specified, and (2) spectral densities are additive. The ability to specify the measuring condition rigorously

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† A fuller discussion of color sensitometry may be found in C. F. J. Overhage, editor: *Principles of Color Sensitometry* (Report of the Color Sensitometry Subcommittee of the Society of Motion Picture and Television Engineers, New York, N. Y., March 15, 1950).

‡ M. H. Sweet: Integral density-densitometry of color film. J. SMPTE, Vol. 44, p. 421 (June 1945).

means that various parties can build color densitometers independently, following specifications, and expect them to yield equivalent results. Indeed this is the basis of American Standard PH2.1-1952. The fact that densities are additive means that two separate absorbers can be measured independently, and the sum of these two densities will be the density of the superimposed combination.

The form of integral density measured with monochromatic light is *integral spectral density*. It is the spectral density of the image taken as a whole and is equal to the sum of the spectral densities of all component absorbers as they operate in the composite film.

Figure 1 shows the spectral density vs. wavelength relationship for a typical three-component monopack film, and serves to illustrate the various types of density. In such a film the color image results from the superposition of three component absorbers, usually referred to as yellow, magenta and cyan. Their *analytical spectral density* vs. wavelength curves are labeled Y, M, and C. The maximum spectral density of each component absorber is called *peak density*. The peak densities of the three absorbers occur at wavelengths λ_y, λ_m and λ_c. Curve S represents the *integral spectral density* of the film. The yellow component of the sample illustrated in Figure 1 has a *peak density* of 1.2 at 445 millimicrons but, because the magenta and cyan components also have appreciable densities at that wavelength, the sample as a whole has an *integral spectral density* of 1.8 at 445 millimicrons.

Specific Provisions of the Color Density Standard

American Standard for Spectral Diffuse Densities of Three-Component Subtractive Color Films, PH2.1-1952 specifies the spectral conditions for measuring integral spectral density. The geometric conditions are those for diffuse density as specified in American Standard for Diffuse Transmission Density, Z 38.2.5-1946. The concepts of *integral spectral density* and the other forms of color density just discussed were already established and in use. The main problem of preparing the standard was to select three specific wavelength bands, and find a practical means of specifying them.

Common practice is to measure the densities at the wavelength of peak density, for at this wavelength the data show with maximum sensitivity small variations of any one of the three components. A problem arises because different types of three-component monopack film use different dye components with somewhat different spectral-density distributions. There is, therefore, no unique set of wavelengths that is optimal for the measurement of all such films. However, it was the concensus of the group that the use of three, and only three, wavelengths for this type of measurement carries the advantage of uniformity of results among instruments of different manufacture and permits specification of a useful standard of performance. These advantages in general far outweigh the disadvantages of not measuring at exactly the peak wavelengths for any particular product. Reaching this conclusion and agreeing on the three wavelengths was the hardest job of the subcommittee.

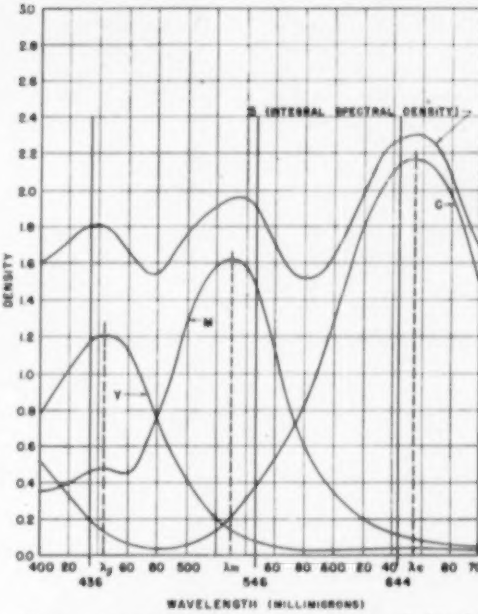

Fig. 1. Spectral density vs wavelength relationship for a typical three-component monopack film.

The three wavelengths chosen were 435.8 millimicrons, 546.1 millimicrons, and 643.8 millimicrons. These should be satisfactory for all types of film now in use. The chief merit of these particular wavelengths is that they are emitted by mercury (435.8, 546.1) and cadmium (643.8) low pressure arc lamps, hence the specification is independent of wavelength units and calibration errors. Densities measured using these emission lines are designated Mercury Blue Diffuse Density, Mercury Green Diffuse Density and Cadmium Red Diffuse Density.

Recognizing that it is not always convenient or necessary to use emission lines from arc lamps for practical densitometry, provision was made for the use of broader spectral bands in practical densitometers. These are satisfactory so long as they give results which, for the intended application, do not differ significantly from those obtained with the standard wavelengths. The exact nature of the acceptable distribution will depend upon the use to which the densitometer is to be put. Such specification is therefore, avoided, and each practical densitometer can be validated for a prescribed type of film by comparison of its results with density measurements made on the same film using the standard wavelengths.

Density measurements made on practical densitometers so validated are designated American Standard Blue Density, American Standard Green Density, and American Standard Red Density.

Influence of Color Density Standard

The outstanding value of American Standard PH2.1-1952 is that it provides a firm basis for uniform practice in color densitometry. By specifying definite spectral

and geometric conditions, it eliminates the baffling array of choices of conditions which otherwise would confront the designer of a color densitometer. It is probably no exaggeration to say that without such guidance no two densitometers of different manufacture would ever read alike.

By basing the specification in terms of the emission lines from available arc sources, the problem of validating a densitometer is greatly simplified. As an example of this benefit, one film manufacturer has found the Standard helpful in adjusting several different instruments *of the same design* so they would yield nearly identical readings.

As the use of natural color photographic films becomes more prevalent, the transmittal of film data, say between the film manufacturer and the processing laboratory, becomes increasingly important for obtaining best results from the film. The ability to obtain similar density data at various locations greatly facilitates the transmittal of information.

GOOD NEWS FROM OVERSEAS

The Council of the International Organization for Standardization (ISO) on 21 May 1954 decided by correspondence to accept ISO Recommendation Number 5 "Diffuse Transmission Density" and ISO/R 6 "Method for Determining Photographic Speed and Exposure Index".

Photographers everywhere should applaud this evidence that international agreements among many countries are possible and that photography has provided the means for 34 countries to express their common need for unity.

Workers in photographic sensitometry will welcome the international method for measuring photographic density.

All picture takers, amateur and professional alike, may rejoice that international agreement has been achieved concerning the expression of film sensitivity. The international recommendation is based on the Exposure Index method that became an American Standard 5 March 1946.

International approval of ISO/R 6 should end forever the confusion created by continual, thoughtless reference in printed matter to antique and outmoded film speed rating systems. Obsolete methods such as H & D, Scheiner, and DIN, may now take their place in history as stepping stones towards the new world unanimity.

HIGH-SPEED FRAMING CAMERA

Producing high-resolution photographs at rates as high as 2.4 million per second, the new Model 222 Beckman & Whitley Framing Camera serves the research needs of workers in combustion, corona-discharge, explosion, plastic- and elastic-deformation, and shock-wave phenomena.

An image of the subject matter is focused on the stainless- or alloy-steel turbine-mirror through a highly-corrected 24-inch achromat. This image is relayed 1-to-1 to the film plane on a 30-inch radius through 25 pairs of adjustable achromats. Plano-concave, field-flattener lenses are located at each frame position within 0.002 inches of the film emulsion surface. A total of 25 frames per run can thus be exposed on stationary perforated 35mm film.

Cameras are operable with the objective lens oriented in either a vertical or a horizontal plane. The turbine-driven mirror is spun to speeds of 5,000 revolutions per second to 10,000 rps, and is driven with helium. An oil system in the camera base provides filtered oil under pressure for lubrication and cooling of mirror bearings and is interlocked for a fail-safe control of camera operation.

The camera is controlled from a rack-mounted unit (shown in the illustration, right) which can be located up to 35 feet away from the camera. This unit contains an event-per-unit-time (EPUT) meter which accurately measures mirror turbine speed; a variable-time-delay generator by means of which the event-firing pulse can be synchronized with the mirror position to expose Frame No. 1 at the beginning of the event; and controls for turbine speed and firing of the event to be recorded. Still pictures can also be taken for convenience in setting up the test.

Optical characteristics of the camera system include the following: (1) effective aperture is approximately f/14.5; (2) resolution in the time direction is 50 lines per millimeter, in the space direction, 100 lines per millimeter; (3) exposure time is 3×10^{-7} seconds at 5,000 rps; (4) frame size is $^3/_4$ by 1 inch; and (5) focus range of the objective lens is 7 feet to infinity.